Fluoroscopes and Fluoroscopy[1]

Carman Lecture

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IT IS CUSTOMARY for the speakers whom you honor with this opportunity to begin their addresses with biographic notes and well deserved praise of the great Russell D. Carman, flavored, if the speaker was so fortunate as to have known Doctor Carman personally, by many an attractive little anecdote, with which the lore of Carman abounds (3, 37).

I, too, knew and loved Russell Carman during his lifetime, as I cherish and revere his memory today. He was more than seventeen years my senior and I well remember the awe with which I first entered his commanding presence. How quickly the geniality and warmth of his personality dispelled my anxiety! His attitude toward us youngsters in the specialty was obviously ideal, and none of us failed to appreciate that he was our friend even before he knew where we were from or what we expected of him.

There is another "Carman Lecture" in these United States, sponsored by the Minnesota Radiological Society and delivered annually at the meeting of the Minnesota State Medical Association. On June 25, 1935, the inimitable Percy Brown used as his title for that Carman Lecture, "The Inception and Development of Fluoroscopy: The Influence of Carman on Its

Status in America" (3). The result was a masterpiece, in the best Percy Brown tradition.

The journals of state medical societies are seldom as widely read as they deserve, and *Minnesota Medicine* is no exception. Instead of attempting to add my bit to the large and still growing lexicon of Russell Carman's biography, I am urging your editors and officers to republish, this time in RADIOLOGY, the 1935 address by Percy Brown. Then, if my paper this evening should be deemed worthy of publication, it would make me very happy to have it appear as a sort of technical appendix to Doctor Brown's masterpiece.[2]

For nearly half a century physicists and engineers have devoted themselves to the advancement of roentgenology. Today we have access to apparatus which was undreamed of a few years ago. But these spectacular advances in method and equipment have practically all been in the fields of therapy and roentgenography. Fluoroscopy is much as it was when Carman's first edition appeared in 1917 (8). In fact, there is remarkably little difference between the 1941 models of commercially available fluoroscopes and the one Bob Kelley sold my father back in 1912 (Figs. 1-A and 1-B). And this, in spite of the

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[1] Read before the Radiological Society of North America, at the Twenty-seventh Annual Meeting, San Francisco, Dec. 2, 1941.

[2] The Editors have gladly acceded to Doctor Chamberlain's request and with Doctor Brown's permission republish his paper in this issue. See page 414.

fact that changes in equipment for therapy and roentgenography have been so marked that there is little resemblance between the apparatus of today and that of earlier years.

I do not mean that there have been no changes or improvements. In matters affecting convenience and maneuverability, steady progress has been made. Most tilting fluoroscopic tables are now motor-driven; we are today so accustomed to the shock-proof feature that we scarcely recall the days when corona made our fluoroscopic rooms reek of ozone, and we had to warn our patients and assistants to avoid getting too near the high-tension leads; from the standpoint of mechanical design, some really new departures have appeared.

A good example of progress in mechanical design is Dr. John Camp's two-way tilt table, especially designed for lipiodol myelography, but applicable and of advantage in many routine procedures. By an ingenious system of interlocked fulcra (see Fig. 1-C) and an entirely new type of drive, which substitutes cranks and connecting rods for the customary rack and pinion, Doctor Camp's table possesses a full 180 degrees of tilt motion, so that it will stand erect upon either end.[3]

In 1924, Schittenhelm and Wels described a special "multiplane" fluoroscope for use with artificial pneumoperitoneum (see Fig. 1-D). This ingenious device surely deserves more attention than it has thus far received. Now that we have facilities for rendering it shock-proof, its

[3] The usual arrangement for tilting a fluoroscope on a fixed axis or bearing commonly introduces a problem of clearances. Sometimes the design is such as to prevent the employment of target-skin (table top) distances greater than 15 or 16 inches. Later in this paper the advisability of much greater distances will be emphasized. Before such "telefluoroscopic" features can be built into the conventional types of tilt-table fluoroscopes that are on the market today, it is usually necessary to (a) introduce an undesirable increase in the height of the table top above the floor, and (b) do away with the portion of the tilt that lowers the patient's head ("Trendelenburg"). A study of Doctor Camp's table has suggested to the author that it would be possible to take advantage of the absence of the usual fixed axis or bearing, to obtain up to 30 inches of target-table top distance, without the necessity of raising the table above the usual 34 to 34.5 inches, and without discarding the Trendelenburg feature.

extreme flexibility could be put to excellent use. For example, the cardiac end of the stomach and the occasional "hidden pylorus" might be expected to reveal themselves with greater reliability in the unusual positions and directions of projection of the fluoroscopic beam made possible by this device.

When I arrived at Temple University Hospital eleven years ago, Dr. Chevalier Jackson had just organized and equipped the fine new Bronchoscopic Clinic in which he was to spend the last of his many illustrious years of active practice. Naturally, when Doctor Jackson threw in his lot with Temple, the University did not stint in equipping his new department, and the biplane fluoroscope which was installed there was the best that was procurable at that time. Soon after my arrival, I found myself in the fluoroscopic room with Doctor Jackson, a number of his assistants, and a little patient with a pin in her lung. A half hour later the pin had been recovered, through the bronchoscope, but I came away from that experience with a determination to do something to improve the fluoroscopic features of Doctor Jackson's work. It was obvious that the help he was getting from the fluoroscopist was inadequate and that many of the shortcomings of the equipment were remediable. I sat down and made a memorandum of the more obvious ways in which the apparatus and the method were at fault.

The intensity of illumination, particularly in the lateral beam, was inadequate, and the fact that oil-immersed units were used to make the equipment shock-proof imposed definite limitations upon the intensity of beam that could be employed. On account of these limitations of output, inherent in the oil-immersed units, in which the voltage factor was particularly limited, the apparatus was necessarily operated quite close to the patient. This resulted in a high intensity at the patient's skin in spite of a low intensity at the screen. My r-meter disclosed the fact that operation of the lateral beam for as little as twenty minutes would bring us to the limit of
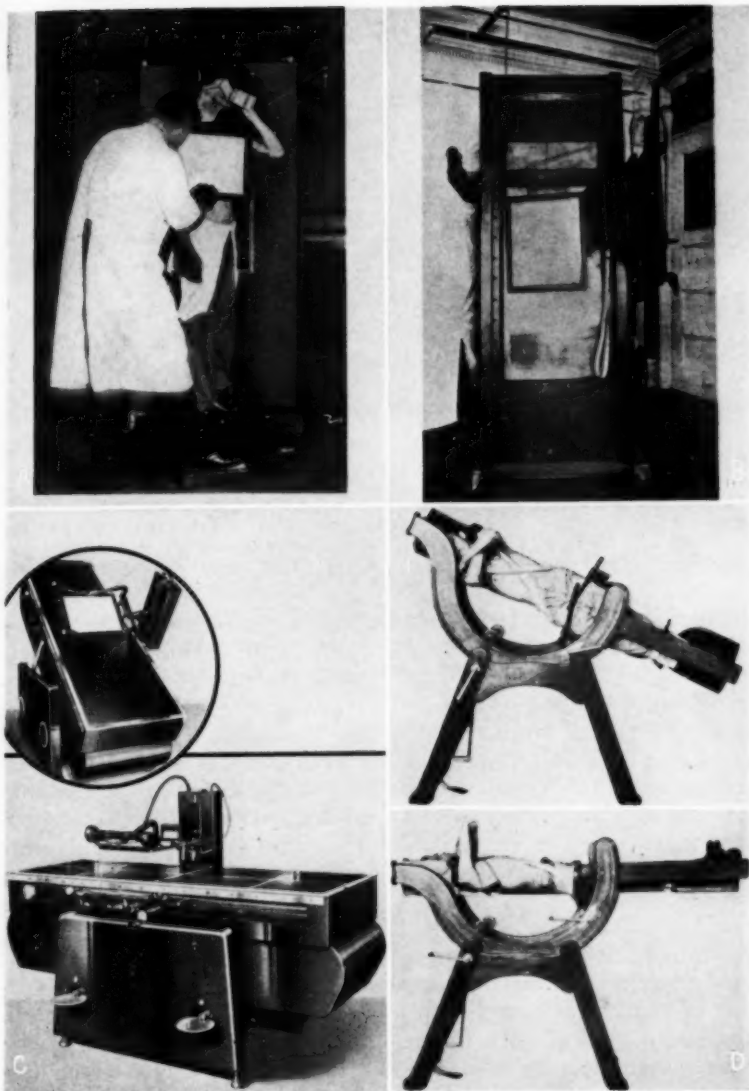
Fig. 1 A. An old "vertical" fluoroscope, pictured on page 40 of the 1917 edition of Carman and Miller: "The Roentgen Diagnosis of Diseases of the Alimentary Canal." Note the similarity to existing types. Such improvements as have occurred have been purely mechanical and in no sense fundamental.

B. An early fluoroscope of the "tilting" type, designed by Doctor Eugene Caldwell. (Photograph from Am. J. Roentgenol. 5: 561, 1918.)

C. Dr. John D. Camp's two-way tilt table, especially designed for lipiodol myelography but of interest here because its novel system of connecting rods and fulcra, replacing the usual axle and gear-segment, could open the way to a desirable increase in target-screen and target-skin distances.

D. The device of Schittenhelm and Wels for mechanically increasing the flexibility of fluoroscopy in connection with pneumoperitoneum. With modern cable-connected shock-proof tubes it offers possibilities of improving the reliability of roentgen diagnosis in the gastro-intestinal tract. (Photograph from "Lehrbuch der Röntgendiagnostik," Springer, Berlin, 1924, p 986.)
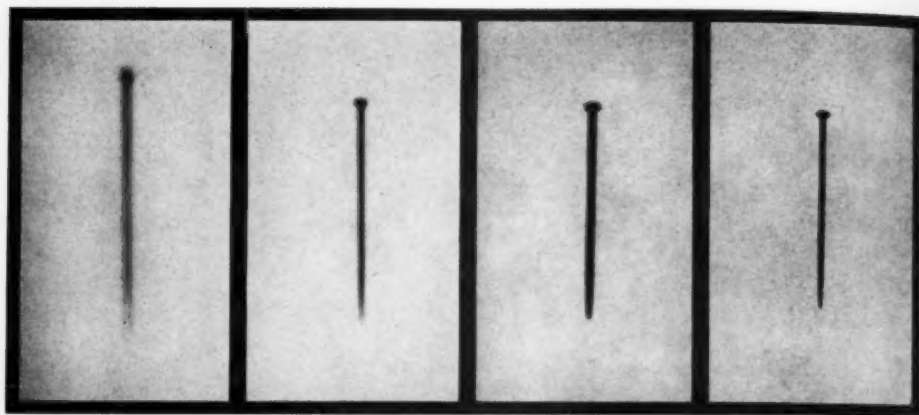
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Fig. 2.   Entirely aside from its salutary effect upon x-ray exposure of the patient's skin (see Fig. 4 and Table I), increase of the target-screen (and target-skin) distance produces marked improvement in sharpness. In each of the four fluoroscopic procedures pictured here, the foreign body, an ordinary straight pin, was 6 inches from the screen.   The target-screen distances were, respectively, 16, 25, 30 and 48 inches.   The tube was a "round-focus," "radiator" type such as was frequently used ten years ago in oil-immersed, shock-proof fluoroscopes for biplane guidance of the bronchoscopist.   With the shorter distances the observed shadow was sometimes entirely penumbral.

safety.   A further untoward result of the necessarily short target-skin distance was crowding of the all-important "head holder," the assistant to the bronchoscopist upon whom devolves the responsibility of maintaining the patient's head and neck in the proper position for the bronchoscopic procedure.   From my first experience I could see that the carefully studied technic for which Doctor Jackson is famous was being dangerously disrupted by manipulation of the biplane fluoroscope.   The huge oil tanks in which were mounted the x-ray tubes and transformers were banging into the shins of the bronchoscopist and displacing the "head holder" to a degree which made his work almost impossible.

Another untoward result of the unfortunate closeness of the x-ray tube focal spot to the patient was the blurring of the shadow of the foreign body.   The distance of the pin from the screen was great enough and the focal spot of the x-ray tube broad enough so that the shadow of the foreign body was almost entirely penumbral.   As a matter of fact, I am not sure that any of the umbra reached the screen (see Fig. 2).

I was fortunate in having as my engineer Mr. O. C. Hollstein, an exceptionally fine mechanic who had worked with Dessauer and other well known radiologists before coming to America from Germany in 1929. Stimulated by a close proximity to Chevalier Jackson and inspired by his unselfish devotion to the welfare of his patients, we began to build fluoroscopes with various novel features.   The model which has stood the test of time is shown in Fig. 3, but we arrived at our goal a little at a time and I think we would have to assign the number 5 or 6 to this particular apparatus, which has remained continuously in service for the past six or seven years.

The special features of this apparatus are, briefly, as follows:

1. Adequate target-screen (and target-skin) distances, the normal operating positions of the screen being, respectively, 48 inches from the horizontal beam focal spot and 54 inches from the vertical beam focal spot.   The corresponding focal-skin distances are, respectively, 36 and 44 inches.

2. Relatively high energies in both x-ray beams, made possible through the use of water-cooled tubes at voltages up to 110 kv.p. and currents up to 18 ma. for short exposures, and up to 6 ma. for continuous or nearly continuous operation.
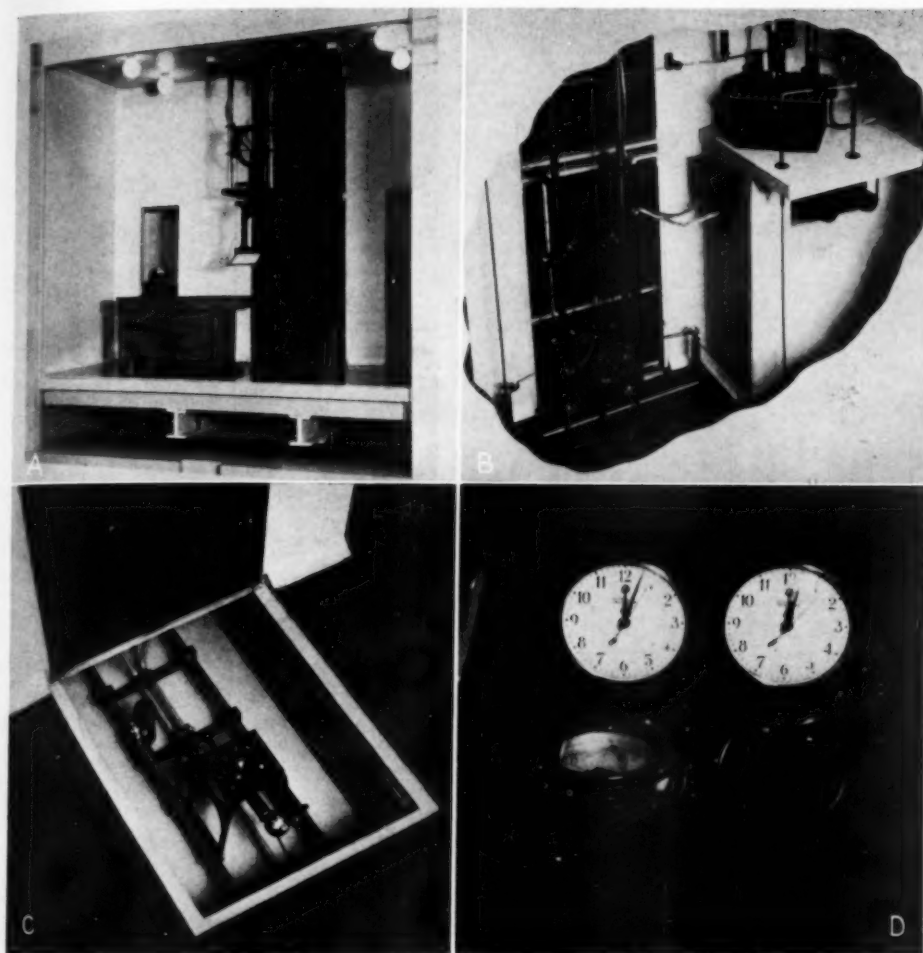
Fig. 3. Home-made biplane fluoroscope at Temple University Hospital.

A. Photograph of an accurately proportioned model, permitting visualization of much detail which is hidden in the case of the device itself. X-ray tube for vertical ray is situated below bakelite panel in steel floor plate, resulting in approximately 54 inches target-screen distance. X-ray tube for lateral beam is situated behind bakelite panel in wall. Toggle switches and push buttons, on screen support within easy reach of radiologist, control electrically driven fluoroscopic shutters, high tension switch for selection of beam, and booster for momentarily increasing brightness of screen.

B. Photograph of high tension compartment behind wall panel to show steel tubing framework, horizontal beam x-ray tube, remote controlled motor-driven high-tension switch and x-ray transformer on shelf.

C. Photograph of vertical beam x-ray tube and its mounting after removal of steel floor plate. The electric motor which drives the cross-travel of the vertical beam tube is seen at the left. Remote control for this is situated on the member which supports the fluoroscopic screen.

D. Self-starting electric clocks are connected so that they record, respectively, the times of operation of the vertical beam and horizontal beam x-ray tubes. This is accomplished through low-tension switch operating in concert with high-tension selector switch. At the beginning of each procedure the clocks are set at 12. Such electric clocks of the self-starting type are available everywhere at prices below $5.

3. A system of remote controls, through finger-tip push buttons and toggle switches, with which the operator chooses the desired shutter openings, which of the two x-ray beams is desired, and which of two available power settings is needed at any particular moment.

4. Rigid correlation of screen move-

TABLE I: RATIO BETWEEN r PER MINUTE AT PATIENT'S SKIN AND r PER MINUTE AT THE FLUOROSCOPIC SCREEN, FOR VARIOUS FLUOROSCOPIC TECHNICS

Type of Fluoroscope; A or B*	Kv.p.	Ma.	Cm. Thickness of Presswood Phantom	Inches Equivalent Thickness of Human Body	Distance Focal Spot to "Skin" (Surface of Phantom) (Table Top)	Distance Focal Spot to Screen	Distance Table Top to Screen	r/Min. at Screen (R₁)	r/Min. at "Skin" (R₀)	Size of Illuminated Area at Screen	Ratio R₀/R₁
B	60	8	20 cm.	Abdomen 7 in.	13 in.	24 in.	11 in.	0.0225	56.4	5 cm. × 5 cm.	2,500
B	60	8	20 cm.	7 inch abd.	26 in.	37 in.	11 in.	0.0118	17.8	5 cm. × 5 cm.	1,510
B	60	8	20 cm.	7 inch abd.	37 in.	48 in.	11 in.	0.0066	8.8	5 cm. × 5 cm.	1,340
B	80	8	20 cm.	7 inch abd.	13 in.	24 in.	11 in.	0.033	46.0	5 cm. × 5 cm.	1,390
B	80	8	20 cm.	7 inch abd.	26 in.	37 in.	11 in.	0.0307	25.8	5 cm. × 5 cm.	840
B	80	8	20 cm.	7 inch abd.	37 in.	48 in.	11 in.	0.0174	12.85	5 cm. × 5 cm.	740
B	100	4	20 cm.	7 inch abd.	13 in.	24 in.	11 in.	0.0758	68.2	5 cm. × 5 cm.	900
B	100	8	20 cm.	7 inch abd.	26 in.	37 in.	11 in.	0.0696	38.3	5 cm. × 5 cm.	550
B	100	8	20 cm.	7 inch abd.	26 in.	37 in.	11 in.	0.1612	43.1	20 cm. × 20 cm.	270
B	100	8	20 cm.	7 inch abd.	37 in.	48 in.	11 in.	0.039	18.9	5 cm. × 5 cm.	485
B	60	8	10 cm.	8 in. thick thorax	26 in.	37 in.	11 in.	0.118	17.8	5 cm. × 5 cm.	150
B	80	8	10 cm.	8 in. thick thorax	26 in.	37 in.	11 in.	0.316	25.8	5 cm. × 5 cm.	82
B	100	8	10 cm.	8 in. thick thorax	26 in.	37 in.	11 in.	0.651	38.3	5 cm. × 5 cm.	59
A	70	4	10 cm.	8 in. thick thorax	11 in.	23 in.	12 in.	0.1924	30.0	15 cm. × 15 cm.	156
A	79	4	15 cm.	5 in. thigh	11 in.	23 in.	12 in.	0.0713	30.0	15 cm. × 15 cm.	421
A	79	4	20 cm.	7 inch abd.	11 in.	23 in.	12 in.	0.027	30.0	15 cm. × 15 cm.	1,110
A	79	4	25 cm.	8 1/2 inch abd.	11 in.	23 in.	12 in.	0.0127	30.0	15 cm. × 15 cm.	2,360
A	79	4	27 cm.	9 1/4 inch abd.	11 in.	23 in.	12 in.	0.0099	30.0	15 cm. × 15 cm.	3,030

* Type A is a commercially available fluoroscope of conventional design with "oil-immersed" unit (x-ray tube and transformer in same oil tank), for "self-rectified" operation. Type B is a home-made device using cable-connected, oil-insulated, oil-cooled x-ray tube and 4-valve, full-wave-rectified transformer (see Figs. 4-B and 7-B). At 4 to 8 milliamperes the wave form approaches "constant potential" because of condenser effect of the unusually long (40 feet) shock-proof cables.
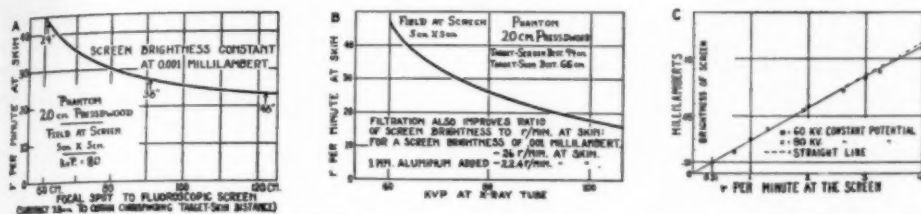
Fig. 4 A. Reference to Table I will indicate the purpose of these graphs. Note that target-skin distances were 13, 25 and 37 inches when target-screen distances were 24, 36 and 48 inches, respectively. Careful comparison of human abdomens with presswood phantoms indicates that 20 cm. of presswood is equivalent to an abdomen 17.5 cm. (7 inches) thick.

B. Elevation of the voltage is an extremely efficient method of reducing the intensity at the patient's skin for a given fluoroscopic screen brightness. If the "inherent filter" (window of x-ray tube plus table top, etc.) is not unusually thin, added filtration produces only moderate decrease in intensity at the skin. The effect of added filtration, recorded here, was obtained at 80 kv.p.

C. From this graph it becomes apparent at once that response of the Type B Patterson screen is approximately linear with respect to r per minute reaching the screen. Like intensifying screens used with x-ray film, fluoroscopic screens have a temperature coefficient (brightness is increased with reduction of the temperature), but within the ordinary range of room temperatures that obtain in clinical fluoroscopy this is entirely unimportant.

ments with x-ray tube and fluoroscopic shutter movements so that the x-ray beam will always fall upon the protective lead glass shield after it has traversed the fluorescent screen.

5. No interference with the work of the bronchoscopist or his assistants, since, with the exception of the screen and its support, the apparatus is either beneath the floor panel or behind the side wall, which is an ample distance from the bronchoscopic table.

More important to our present purpose than mere description of this device is an account of what we have learned from its use. It taught us that marked increase of the target-skin and target-screen distance is worth going after because it reduces distortion, increases resolving power (fineness of detail in the screen image), and, when accompanied by an appropriate increase in the voltage factor, reduces quite spectacularly the biologic effects upon the patient's skin for a given degree of illumination at the screen (see Fig. 4 and Table I). How great is this reduction of skin effect can be learned from the following measurements. Operating the x-ray tubes at 6 ma. and 100 kv.p. (four-valve, full-wave rectified transformer), we found visibility relatively good, definitely superior to that obtained with commercially available fluoroscopes, and roentgen exposure at the

patient's skin only 2.45 r per minute for the vertical ray and 4.45 r per minute for the horizontal ray.[4]

When we increased the distance, as a result of our anxiety to avoid crowding the "head holder" during bronchoscopic procedures, we felt that the highest energies that we could possibly impose upon even the water-cooled tube in the open air would be inadequate from the standpoint of illumination of the screen. We therefore installed a push-button control at the fluoro-

[4] I once measured the exposure at the patient's skin in more than twenty fluoroscopes of conventional design, some of the horizontal type, some of the vertical type, and many of the tilting type, and found that with routine operating factors actually in use with these devices, usually 4 ma. but sometimes 5 ma., skin exposures varied from 20 r per minute up to as much as 48 r per minute. Not one commercially available model was discovered in this survey with less than 20 r per minute at the patient's skin.

Doctor Garland (17) made a similar survey in San Francisco and got a range of 8 to 18 r per minute. He states his figures, however, in the following words: "If the target-skin distance is 18 inches and a thin aluminum filter is used, the patient's skin gets from 8 to 18 roentgens per minute (as measured by the author on different installations)." It is reassuring to hear that there are commercially available fluoroscopes with as much as 18 inches between focal spot and patient's skin. In my own survey, made several years ago, the target-skin distances ranged from 11 to 14 inches, which probably accounts for the difference between Doctor Garland's findings and mine. Another instance of the effectiveness of increasing the distance factor in fluoroscopy, in reducing exposure of patient's skin, is afforded by a special installation we recently completed in connection with a tilt-table, involving a target-skin distance of 26 inches. With this device the r-per-minute at the patient's skin is relatively low (19 r per minute) even when the energy input is as high as 80 kv.p. and 8 ma.

scopic screen, enabling us to momentarily impose higher energies. Thus, while operating at 6 ma. and 100 kv.p., the fluoroscopist could press a button and elevate the voltage to 110 kv.p. while at the same time stepping up the current to 18 or 20 ma. Even with the tube hot and water boiling we found it possible to impose such energies for two or three seconds at a time, without apparent danger to the tube. This stepping up of the energies increased the exposure at the patient's skin to approximately 14 r per minute for the horizontal ray and 9 r per minute for the vertical ray. It at once became apparent that when these high energies were utilized for one or two seconds at a time, a foreign body which was thus visualized often remained visible after a return to the lower energies. In other words, the brightness of the screen having been brought up to a high enough level so that better perception was possible, a return to the lower level of energy input (and screen brightness) did not result in a disappearance of the observed details. We now knew what we were looking at and it remained visible in a very reassuring way. From these experiences we developed the conviction that every fluoroscope should have on it some arrangement of push buttons to permit momentary activation at higher energy levels than would ordinarily be thought safe or appropriate. It has been our experience that, whenever a fluoroscope has been so equipped, it at once becomes the custom of its users to employ much lower energies than were formerly employed. In other words, having at hand, subject merely to the pressing of a button, higher energy levels than were formerly available, the fluoroscopist tends to make his standard foot switch setting at an energy level which is considerably lower than the one he would choose were he limited to a single setting. The installation of these remote control push-button devices, where the fluoroscopist can easily actuate them, thus becomes a safety factor both from the standpoint of the patient's skin and from the standpoint of the fluoroscopist's protection from scattered ray.

By this time some of you may be skeptical of the effectiveness of a fluoroscopic device which utilizes such high voltages and employs such unorthodox target-screen distances. What of the actual results? I must yield to the temptation to tell you the story of one of our biggest biplane fluoroscopic thrills.

A few months after we had finished our technical developments, and at a time when our confidence in the new device was growing steadily, Doctor Jackson received a letter from a bronchoscopist in another city. The gist of it was that a Mrs. R., age about 50, of a very thick and stocky build, had inhaled a very small and elusive straight pin and had wisely applied to have it removed. The pin was located in one of the smallest branches of the axillary basal segment of the right lower lobe, far down in the costophrenic angle, and its visualization was so difficult that fluoroscopically it was seen only in the vertical (P.A.) beam, and then only indistinctly.

Attempts had been made to remove the pin through the bronchoscope, but inability to visualize it with the lateral beam had prevented success. After the first two failures, it was thought that a different biplane fluoroscope might turn the trick and the case was transferred to another institution, but to no avail. Finally the assistance of a manufacturer was enlisted and a special biplane fluoroscope was improvised, using broader focus tubes so that the current could be increased, at least momentarily. This last attempt had also been unsuccessful, again due to the fact that the foreign body could be seen in only one plane. Upon learning that no further attempts at removal were contemplated, the patient had asked if she might go to Philadelphia to consult Doctor Jackson.

The letter emphasized the fact that the difficulty was *fluoroscopic*, not bronchoscopic, and apparently insurmountable. It closed with the suggestion that Doctor Jackson write a letter designed to save everyone time and trouble by explaining the futility of a journey to Philadelphia. Doctor Jackson showed the letter to me

and I said: "Couldn't we please get the patient to come?" because, if there was a foreign body in a lung that could be visualized on roentgenograms yet not by fluoroscopy, we wanted it for its value as a sort of "test-object."

In due time, and after some additional correspondence, Mrs. R. arrived, accompanied by the bronchoscopist and the roentgenologist who had formed the original team. Incidentally, the roentgenologist was an old friend of mine and the bronchoscopist was, of course, one of Doctor Jackson's former students, and both were very welcome in our workshop.

I made everyone wait a full forty minutes for dark adaptation and when we were ready I was able to show them the shadow of the pin in both planes. The removal was quite dramatic, and soon accomplished. The necessary information as to the relationship of the point of the pin to the jaws of the forward-grasping forceps was readily provided by both beams of the fluoroscope. Under such circumstances the effect of Doctor Jackson's quiet precision is to give the impression that failure is utterly impossible. Our visitors gave us quite an ovation and we felt that our home-made biplane fluoroscope had won its spurs.

Another of our home-made fluoroscopic contraptions merits a brief description at this time (see Fig. 5). We call it our "multiplane fluoroscope," for it gives us a fluoroscopic beam which is rigidly confined to the lead glass protective shield at all times, but is nevertheless readily oriented in practically any direction, from almost any part of the room. Nicely counterweighted and freely movable on its ball-bearing travelling-crane support, this flexible device has become quite indispensable in our fracture work. As some of you know from seeing it in service, it has even given us fluoroscopic guidance for the insertion of the Smith-Petersen nail in cases of fracture of the femoral neck. The small size of its screen, 8 by 10 inches, and the statement that it is used in connection with fracture reductions, might provoke consternation
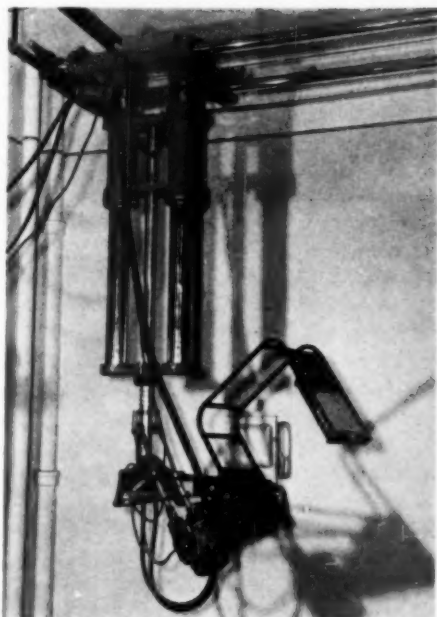

Fig. 5. This home-made "multiplane" fluoroscope at Temple University Hospital was designed particularly for visualizing fracture fragments before and after manipulation, but it has many other possibilities. Note the "traveling crane" type of ceiling mounting to permit free movement about the room. X-ray beam is readily angulated in any direction at the will of the operator. The C-shaped arm which connects tube housing and screen insures correct alignment of x-ray beam with lead glass protection. With this device we have been able to control the insertion of the Smith-Petersen nail in cases of intracapsular fracture of femoral neck.

among old and experienced radiologists. I can only say that our use of this device meets all the requirements of safety, not because of anything inherent in its design, but because of the way in which we operate it.

In the first place, we never permit manipulation of a fracture while the x-ray beam is turned on. All manipulations are carried out with the x-ray turned off and with the room dimly lighted by yellow or red light. Between manipulations, or after a final adjustment, with the hands and other parts of the fracture surgeon and his assistants carefully removed to a place of safety, the fluoroscopic screen image is used as a "check-up." We have succeeded in training the fracture surgeons to look upon this

fluoroscopic glimpse as a safe procedure when carried out carefully, but an extremely dangerous procedure when used in the wrong way.

When this work began, and particularly when the flexibility of the multiplane fluoroscope had been developed to its present degree, there was a tendency for the fracture surgeons to dictate when the x-ray beam should be turned on and when it should be turned off. We realized at once that the radiologist cannot allow the fracture surgeon to subject his hands to the damaging effects of the primary beam just because he claims the right to accept that risk. The responsibility for the safety of all concerned is squarely up to the radiologist. That we succeeded in correcting this difficulty is due to two circumstances. The first was the arrival of some cases of roentgen injury to the hands. In one of these the sufferer, a fracture surgeon, a visitor from a distant city, came to us for advice on account of a roentgen ulcer on one of his fingers. Our own fracture surgeon and professor of orthopedics, Dr. John Royal Moore, was called upon to amputate the injured finger and he saw to it that the younger members of his staff were thoroughly informed as to the reasons for the amputation. When Doctor Moore and his staff submit to the discipline of complete avoidance of x-ray exposure, they know that the dangers we talk about are not purely imaginary.

The other factor that has aided us in enforcing the proper discipline is this. We have succeeded in convincing the fracture surgeons that reduction of fractures under fluoroscopic visualization would, even if it were not dangerous, interfere with their developing special skill as "bone-setters." We like to remind them that a blind man can imbibe from a bowl of soup without soiling his vest because he is habituated to his blindness, but if you or I were to blindfold ourselves we could be pretty sure that the soup would be spilled. In the same way, the fracture surgeon who practises his bone-setting in the moderately dim light of the fluoroscopic room with the x-ray beam turned off is learning something that he can put into practice when he is many miles away from x-ray apparatus. If, on the other hand, he should make it a practice to do his fracture reductions with the x-ray turned on, he would develop a tendency to become dependent upon the fluoroscopic image.

In view of the very satisfactory performance of this home-made "multiplane fluoroscope," with its shock-proof, oil-insulated, cable-connected x-ray tube, and its C-shaped member for maintaining alignment of x-ray beam and screen (and lead glass protection of screen), we have noted with interest some very similar features in the 1941 model of U. S. Army Field Unit. This ingenious development appeals to us as a move in the right direction, and its unique new x-ray tube, with air blower for cooling the housing and "impeller" for circulating the oil to convey anode heat out to the housing, has already made history. In this device, as in ours, the question of adequacy of x-ray protection has been raised. I think we must admit that such flexible devices as these are not *inherently* safe, and that it is up to the operator to adhere to a proper technic. After all, the direct beam is properly collimated, and it is the ray scattered by the patient's tissues that must be guarded against. This is a factor in practically every fluoroscopic procedure in clinical practice.

In this paper I have purposely avoided any attempt to cover the subject of x-ray protection. In the first place, it is a subject by itself, and a big one. In the second place, it has been thoroughly covered in many previous publications by men better qualified than I (2, 10, 11, 12, 13, 14, 15, 23, 28, 29, 44, 46, 52, 53, 56). For present purposes may I simply point out that the necessary instruments and methods of measurement are now available to all of us, so that no one need be in ignorance of the amount of ray he is accumulating, or its relationship to safe limits? X-ray equipment will never be fool-proof and any search for completely "safe" apparatus is bound to be futile. The proper training

of personnel and proper emphasis upon *methods of use* will always be necessary in fluoroscopy as in other branches of the practice of radiology.

Ponthus (40, 41, 42) has outlined a possible method of applying the principles of "body section roentgenography" ("planigraphy," "laminagraphy," etc.) to fluoroscopy. There is room for considerable doubt as to whether such a method will ever achieve practical success. According to the best information I have been able to obtain, neither Ponthus nor anyone else has actually tried the method with x-rays. (Ponthus built a model to illustrate the principle, using a beam of light instead of x-rays.) But the important place which this method's roentgenographic counterpart is making for itself in present day practice seemed to justify calling it to your attention. Figure 6 is taken from one of Ponthus' descriptions of the method.

Stereoscopy is such an important element in the armamentarium of the modern diagnostic roentgenologist that he must often ask himself why it has not been successfully applied to fluoroscopy. Many *theoretically* adequate stereoscopic fluoroscopes have been built, one of the earliest by Caldwell. Dumond (16) has given us a very complete exposition of physical and mathematical principles. Yet stereofluoroscopes continue to gather dust, or go to the junk heap, and none has ever established itself as of sufficient value to warrant its upkeep. The reason for this is inherent in the retinal physiology of the fluoroscopist and it is to this that we must now turn our attention.

The human eye, when used in the interpretation of a roentgenogram, viewed on a proper illuminator, is able to distinguish differences in the brightness of adjacent film areas when those differences are of the order of 1 or 2 per cent. The same eye, even when thoroughly or completely dark-adapted, may require a 20 to 40 per cent intensity difference for discrimination when the brightness is reduced to the low levels that prevail in many fluoroscopic procedures (see Fig. 15). Furthermore, along

with the loss of intensity discrimination goes a comparable loss of visual acuity (see Fig. 16). Since both of these important capacities of the visual apparatus (*i.e.*, "intensity discrimination" and "visual acuity") are grossly altered by the sort of changes in the brightness level that are met with constantly in everyday clinical fluoroscopy, it follows that limitations in fluoroscopic visibility are largely a matter of retinal physiology, and the brightness

SCHEMATIC DIAGRAM
DEVICE OF PONTHUS
FOR
BODY SECTION FLUOROSCOPY

Focal Spot - F Rotates about axis - X, X' as does also the mirror system - M, m. All shadows on Screen - E, E' exhibit circular motion, but shadows of objects in one plane, O, appear stationary when viewed in mirrors.
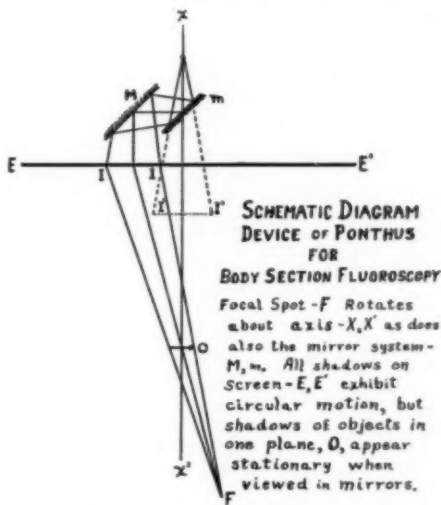
Fig. 6. The method of Ponthus for "planigraphic fluoroscopy," using circular motion. The method has not actually been tried except in the form of a model that employed a beam of light instead of x-rays. With this method the selection of the desired plane for the "cut" would be accomplished through adjustments of the relations of the two mirrors.

level is more important than any other single factor in the physical set-up.

Few radiologists are equipped to make determinations of the output of light by a fluoroscopic screen, in foot-candles, millilamberts, or any other unit of illumination or brightness, and until we know the brightness of the fluoroscopic screen image we cannot even guess as to how much "invisibility" or apparent "unsharpness" is due to the apparatus and how much is due to the inherent limitations of the retina.

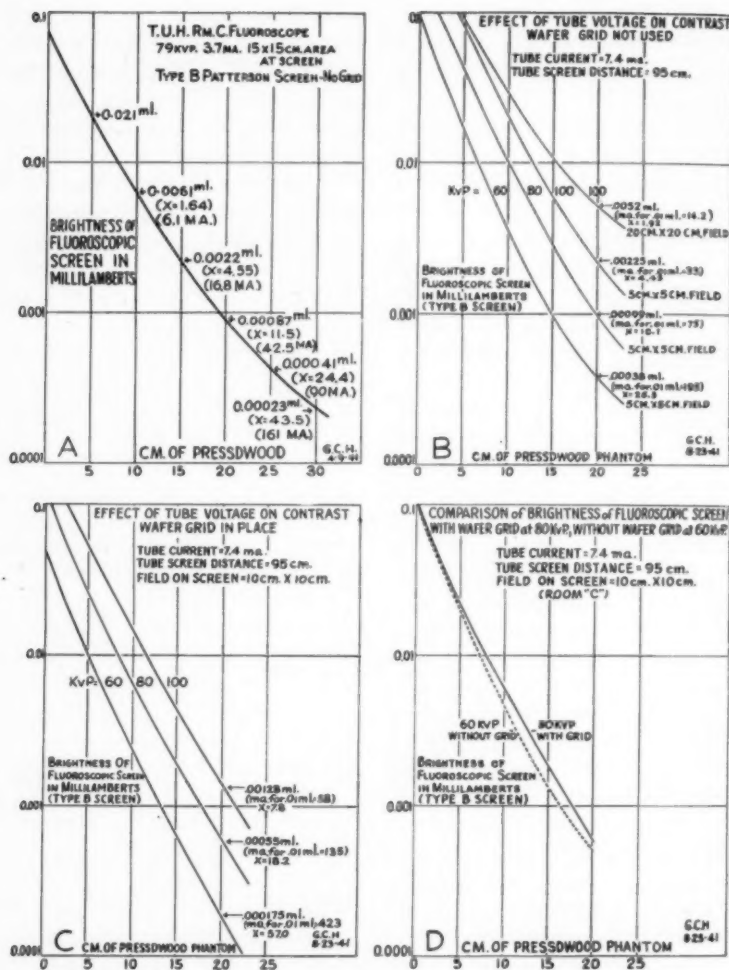This piece of paper held before you in the light of this reading lamp reflects light

Fig. 7 A. The data were obtained with the Macbeth illuminometer (see Fig. 13). "Pressdwood" of 20 cm. thickness is equivalent to an abdomen approximately 17.5 cm. (7 inches) thick, on the average. Pressdwood of 10 cm. thickness is equivalent to lung field when thorax is approximately 20 cm. (8 inches) thick.

Below a brightness of 0.01 millilambert the retinal cones do not function at all and "visual acuity" and "intensity discrimination" are very poor (compare Figs. 15 and 16). On the graph, the various values given to "x" represent the factor which the intensity of the x-ray beam would have to be multiplied by, in order to raise the brightness to 0.01 millilambert. The milliamperage values given for thicknesses of pressdwood 10, 15, 20, 25 and 30 cm. represent the currents that would be necessary, with that particular fluoroscope, to produce a brightness of 0.01 millilambert.

B. The data of B, C, and D were obtained on a very different fluoroscope from those of A. The values given for "x" have the same significance, but are given only for pressdwood phantom thickness 20 cm.

C. A modern wafer grid was interposed between phantom and screen. The data indicate that the brightness level is seriously reduced through the use of a wafer grid and this renders the practice open to considerable question.

D. These graphs suggest that increase in contrast (represented by steepness of the absorption curve) can be obtained approximately as well through a reduction of voltage as through interposition of a wafer grid. But considerations of retinal physiology suggest avoidance of any measure which cuts down brightness.

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at a brightness level of approximately 30 millilamberts. Dr. George C. Henny, to whom I am indebted for many of the original physical data which have made this analysis possible, has shown that under operating conditions in clinical practice the brightness of the Type B Patterson screen is of the order of 0.0001 to 0.01 millilambert (see Fig. 7). For example, in one particular case of a first-class modern fluoroscope operated at 80 kv.p. and 4 ma., 30 r per minute at the patient's skin, a 7-inch-thick abdomen reduced the brightness level to slightly less than 0.001 millilambert. This is 30,000 times dimmer than my piece of paper held here in the light of this reading lamp (see Figs. 7 and 8).

Some of you may be having difficulty in believing this last statement. You may be saying to yourselves that surely you would be aware of such a 30,000-fold difference if your particular fluoroscope were giving such low degrees of brightness. I can assure you that the statement is conservative, and that the reason you and I are unable to appreciate the magnitude of these differences in brightness with our own unaided senses is that our eyes adapt themselves to such changes in brightness by comparable changes in degree of retinal sensitivity. If a brightness of 0.001 millilambert produces an impression of being about one hundredth as bright as this piece of paper held in my hand, instead of the 30,000-fold difference that actually exists, it is because the sensitivity of the eye is thousands of times greater under conditions of complete or moderately complete dark adaptation than under conditions of complete or partial light adaptation.

The degree of sensitivity which the retina develops after a rest in the dark is something to marvel at. After ten or twelve hours in the dark, the threshold brightness reaches a lower limit of one millionth of a millilambert. Someone has recently calculated that the completely dark-adapted human retina, that is, the human retina in its most light-sensitive phase, produces the sensation of vision when but 8 or 9 photons impinge upon the sensitive elements. A single photon within the range of the visible spectrum is able to produce the necessary chemical change in one molecule of visual purple, and from determinations of light intensity at the threshold of vision, it appears that when 8 or 9 molecules of this remarkable compound are thus altered, the brain receives the appropriate stimulus through the optic tracts. This places the retina in a class with such sensitive physical systems as the Geiger counter and the electron multiplier. Yet that same retina, after exposure to
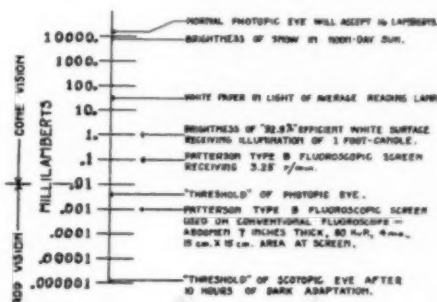

Fig. 8. On our scale we have indicated the change-over between rod vision (low brightness levels) and cone vision (high brightness levels) as though it occurred suddenly at 0.01 millilambert. The transition actually takes place more gradually, in the range between 0.01 and 0.1 millilambert. Even in the range between 1.0 and 0.1 millilambert, where cone vision is operative, deterioration in visual acuity and intensity discrimination with lowering of the brightness level, becomes very noticeable (compare Figs. 15 and 16).

bright light for three minutes, enters a state which we characterize as "light-adapted" in which its threshold (that is, the smallest amount of light which will produce the sensation of vision) has risen to 0.004 millilambert and it is capable of accepting, without injury to itself and with excellent transformation of these energies into the cerebral values of vision, energies as high as 16,000 millilamberts. In other words, its threshold has increased 4,000-fold, and the full range between energies that are acceptable by the completely light-adapted retina and the threshold of sensitivity of the completely dark-adapted eye is more than ten billion-fold (Fig. 8).

In a discussion of fluoroscopy it should

not be necessary to defend a full consideration of retinal physiology and the phenomena of dark adaptation and light adaptation, but experience shows that many users of fluoroscopes are uninformed or misinformed in these important matters. The fluoroscopist who begins an examination before an appropriate degree of dark adaptation has been achieved should at least have knowledge of just what he is throwing away in making that mistake. Without a thorough knowledge of the limitations of his own visual apparatus, the radiologist may be deceived into believing that "invisibility" is significant. A personal anecdote will serve to emphasize this point.

A good many years ago a young man, who has since become a very successful roentgenologist, held the privilege of making fluoroscopic studies in my department, and one day he and I entered the fluoroscopic room together. After a few minutes he signaled for a patient, and I remarked that I was not yet dark-adapted. He expressed surprise and said, "It's a pity that a man who does as much fluoroscopic work as you do, Doctor Chamberlain, has to wait so long for his pupils to dilate." I expressed the thought that perhaps his own visual apparatus was not free from certain known limitations and made a mental note that I must take the first opportunity to explain dark adaptation, which is, of course, very little concerned with dilatation of the pupil and very much concerned with sensitivity of the retina. In the meantime, however, I took advantage of the fact that a recent film of my abdomen had revealed a barium residue in my appendix, and I suggested to the young man that I would like to have him look at my appendix to see whether some barium sulphate which I had been given a few weeks previously was still present. I arranged myself on the fluoroscope and he looked for evidence of a barium residue and announced that there was none. I urged him to look closely because it had not been very long since a film showed the residue still there. He looked again, and again an-

nounced that barium residues were definitely not visible. By this time we had been six or seven minutes in the dark. I am sorry that I cannot give the exact time, but this attempt to visualize the barium in my appendix occurred between patients, and after he had completed at least one patient's fluoroscopy, and I think I am quite conservative in estimating six or seven minutes as the duration of the dark adaptation up to that moment. Ten or fifteen minutes later, after we had completed a number of fluoroscopic observations on a series of patients, I realized that my eyes were at last becoming dark-adapted and I suggested to the young man that I would like to have him look again to make perfectly sure that barium residues were not present in my appendix. He was obviously rather surprised at my request, as he was convinced in his own mind that further fluoroscopy was unnecessary and would reveal nothing. Imagine his surprise when this additional fluoroscopic observation brought to light, very vividly, a definite barium residue in my appendix. With this lesson before him, I think he was better able to appreciate the importance of dark adaptation. Unfortunately, unless great care is taken, there is always danger that absence of fluoroscopic evidence will be given too much weight. Fluoroscopy has inherent limitations even when the radiologist is completely dark-adapted. When we add to these inherent limitations the additional limitations imposed by a deficient dark adaptation, the deficit may add up to a formidable figure.

Physiologists and biophysicists have amassed a tremendous amount of information and knowledge concerning retinal physiology. Many of the more important items in this knowledge were well established eighty years ago. The first edition of Helmholtz' *Handbuch*, published in 1866, contained many of the fundamentals. Much of the information is well organized in textbooks of physiology and psychology, and excellent monographs such as the one by Selig Hecht in *Physiological Reviews*, April 1937 (21), have made
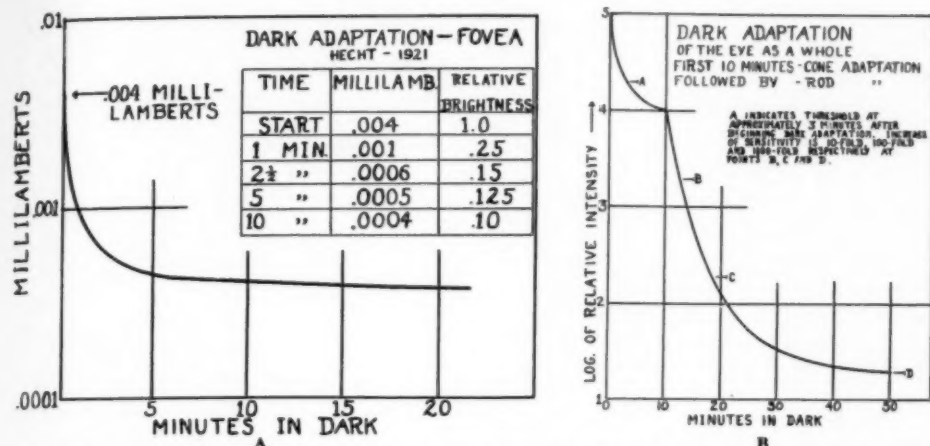
Fig. 9 A.   Mistaken ideas concerning dark adaptation may result from disregard of certain fundamental facts.   (1) The fovea contains no rods;   (2) rods are the only elements which function at the extremely low brightness levels that obtain in practically all clinical fluoroscopy;   (3) the early (first five minutes) and limited (approximately 10-fold) increase of sensitivity shown in this graph deals only with cone function.

B.   Dark adaptation of the rods, obviously all-important in clinical fluoroscopy, begins to be measurable after approximately ten minutes in the dark.   It is 100-fold between the ten- and twenty-minute measurements (at least 1,000-fold for the total twenty-minute interval though not measurable until rods become more sensitive than cones, which occurs at approximately ten minutes).   Sensitivity continues to increase for many hours (compare Fig. 11), though not in comparable degree.   Contrast the 1,000-fold increase during the first twenty minutes with the 5-fold increase during the second twenty minutes.

recent discoveries available to us. In spite of this, misconceptions are rampant. Very recently the science editor of the *New York Times* printed a terrible "break" about "dilatation of the pupil," making it obvious that he is entirely unaware of the changes in sensitivity that occur from instant to instant in the retina, and as recently as May 1941, in the *American Journal of Roentgenology*, we read in an article by Doctor Lerner (31): "It is likewise suggested that from three to five minutes is the optimum time the normal individual should spend in accommodation before roentgenoscoping. The increase in acuity after five minutes being so slight, it is felt that a longer time is not necessary." Contrast with this unfortunate misconception the following quotation from a remarkable pamphlet which was put out by the Committee upon Physiology of Vision of the Medical Research Council in London, England (1). On page 111 of this excellent review we read: "It is well known that in the early stages of dark adaptation (*e.g.*, the first seven minutes) the increase of sensitivity is very small in comparison with

the rapid and marked increase which occurs for the ensuing half hour." Surely there must be some explanation for the discrepancy between Doctor Lerner's suggestion that it is unwise or unnecessary to spend more than three to five minutes in dark adaptation, and the very different data of the biophysicists and physiologists.

The explanation lies in the fact that Doctor Lerner's apparatus and method of plotting results (see Fig. 10-F) were not suited to the measurement of dark adaptation as it affects fluoroscopy. Whether or not his method gives reliable information concerning vitamin A deficiency I will leave to the experts in that field, though I must confess to some skepticism. The important point is that Doctor Lerner's graphs[5] show an approximately 10-fold increase of sensitivity in terms of the threshold of sensation, with the curve flattening out in three to five minutes. This is exactly what the physiologist always obtains if he

[5] The linear scale of threshold intensities used in plotting the data of Fig. 10-F tends to conceal the magnitude of sensitivity increase beyond the first 10-fold change. The log scales of Figs. 9-A, 9-B, 10-A, *et al.*, are more appropriate and informative.
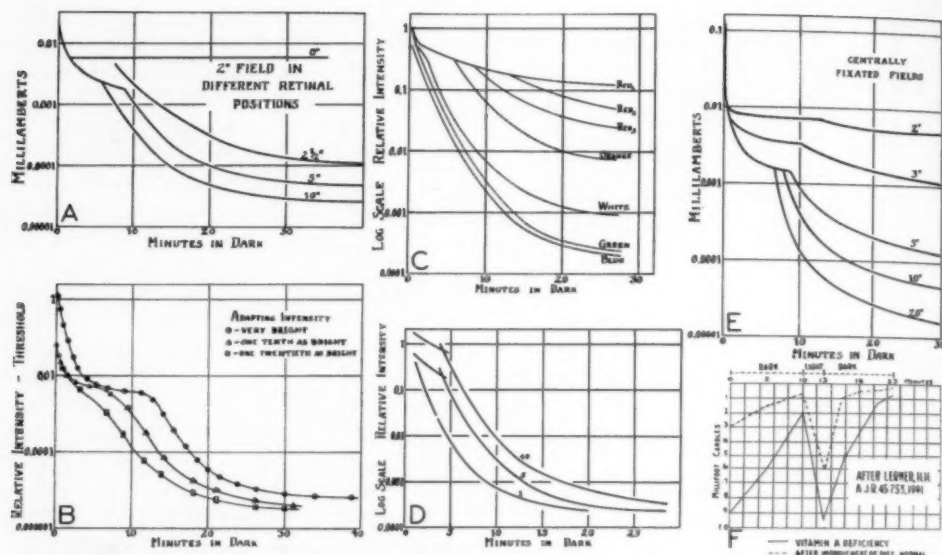
Fig. 10. The nature and degree of dark adaptation of the retina depend upon many factors such as (A) part of retinal field exposed to the testing light, (B) brightness of the "bleaching" light to which the retina was exposed before the beginning of dark adaptation, (C) the color of the testing light, (D) the duration of exposure to the "bleaching" light preceding the dark adaptation experiment, and (E) the area of retina exposed to the testing light.

F. From the preceding graph and a consideration of the data in Fig. 9 it is at once apparent that the method used for the data of Chart F has nothing to do with rod adaptation. Since clinical fluoroscopy is largely (often completely) a matter of rod vision, very different methods of study are required for conclusions regarding fluoroscopic vision (see text).

limits his measurements to cone function (see Fig. 9-A). But most clinical fluoroscopy is concerned with rod function, and until fluoroscopic screens are 100 times as bright as at present, the fact that the fovea centralis, where there are cones, no rods, becomes fully dark-adapted in from three to five minutes will hold little importance for the radiologist.

Retinal physiology, like retinal morphology, is very complicated. No two analyses of retinal function can be reconciled with each other unless we pay due attention to such diverse factors as the area of retina upon which the "bleaching light" impinges (both size and location of area with respect to fovea centralis, etc.), intensity of the illumination, duration of exposure, and color (of the bleaching light). Likewise the data are markedly altered by the corresponding factors in the light which is used for determination of the threshold. Figures 9, 10 and 11 have as their purpose

a graphic presentation of the essential features of dark adaptation (and light adaptation) of the human retina. A few points require amplification.

The complete absence of rods from the fovea (Fig. 11-B) might lead one to expect an absence of cones from parts of the retina at a distance from the fovea, but such is not the case. Cones are present, though in varying proportions and concentrations, in all parts of the retina.

Color vision is a function of the cones. Rods are not concerned in color vision. (Physiologists have learned much by studies of retinal physiology in totally color-blind persons.)

Light of wavelength 6,700 to 7,000 Å. produces the sensation of deep red color through cone vision, but has no effect whatsoever upon the rods. This is important, for it signifies the possibility of obtaining complete dark adaptation of the rods while exposed to intensities of deep
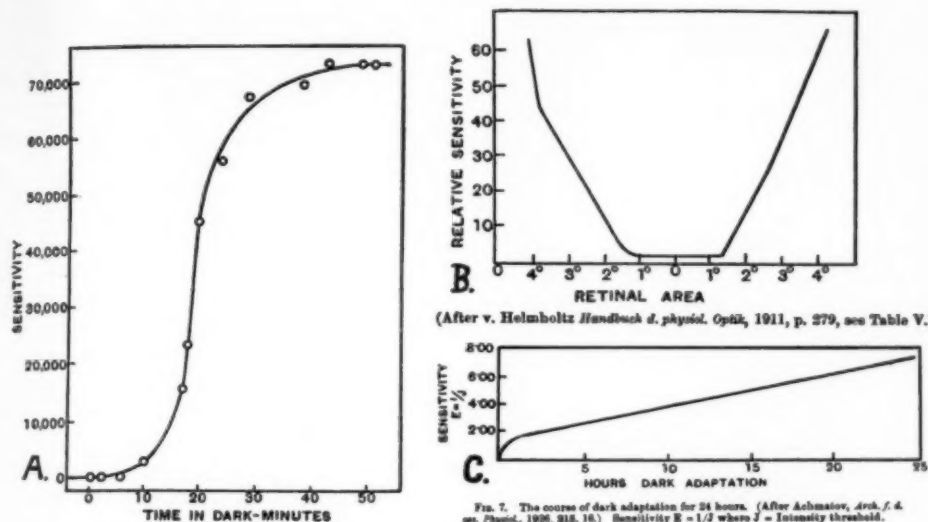
Fig. 11.   Further studies of retinal sensitivity and dark adaptation, taken from Adams (1).
   A.   This graph (credited to Hecht) is plotted from data similar to those of Fig. 9-B, sensitivity being defined as the reciprocal of the threshold intensity.
   B.   The absence of rods from the foveal area accounts for the findings charted here, a graphic representation of the "central scotoma" which accompanies vision at brightness levels below the threshold of cone vision.
   C.   Dark adaptation continues even after several hours, but for obvious reasons this fact is of little importance to the clinical fluoroscopist.

red light sufficient for useful work. By the use of appropriate filters and light source, the clinical fluoroscopist could dark-adapt his eyes without going through the ordeal of complete idleness that has plagued him these many years; if especially radiolucent parts are under scrutiny, so that brightness levels sufficiently high for cone vision are obtainable (above 0.013 to 0.014 millilambert) (see Fig. 7), a wait of three to five minutes would be ample (see Fig. 9-A); for all thicker parts (brightness levels too low for cone vision) adaptation would be complete without even that delay.   For graphic evidence of these peculiarities of rod (colorless) and cone (color discerning) vision, see Figs. 12 and 10-C. This insensitiveness of the rods to deep red light, of wavelength longer than 6,700 Å., accounts for the fact that in a flower garden at twilight, red flowers appear black while the sense of brightness is still forthcoming in the yellows, greens, and blues.

Thus far we have allowed the emphasis to rest upon measurements of threshold intensity. But the really important factors for the clinical fluoroscopist are "intensity discrimination" and "visual acuity," corresponding roughly to "contrast" and "sharpness" in roentgenograms. Figures 15 and 16 serve to visualize the degree to which these features of retinal physiology ("intensity discrimination" and "visual acuity") deteriorate as a result of lowering of the brightness level.   A careful study of these graphs suggests that the deterioration of intensity discrimination is more serious than that of visual acuity. Our experiences with Doctor Jackson's cases of metallic foreign body bear this out. Remarkably small objects can be seen if their shadows are very contrasty.   But most measurements of visual acuity (e.g., the data for Fig. 16) are based upon contours with maximum contrast, to all intents and purposes black on white or white on black, and many of the details in a lung field or abdomen are far less contrasty.   In actual practice, therefore, we suffer from a combination of these two handicaps.   Small wonder that stereofluoroscopy has failed, for stereoscopic vision depends upon perception of detail to an extent that is simply not forthcoming under conditions of clini-
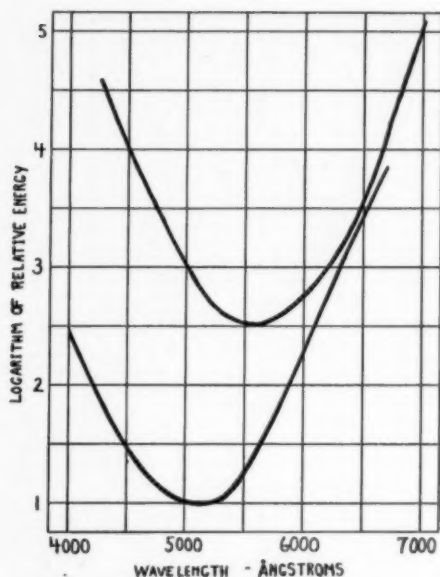
Fig. 12. After Hecht (21) to show the relation between wavelength and relative energy required to produce a specific visual effect at high (cone vision) and at low (rod vision) brightness levels. Note particularly the "blindness" of the rods at wavelengths longer than 6,700 A. Note also that the two curves are nearly coincident at the red end of the spectrum (compare Fig. 10-C).

cal fluoroscopy. Demonstrations of stereo-fluoroscopy using metallic objects, such as wire cages, are extremely misleading, and give no correct idea of what the results will be when (a) the objects being looked for are non-metallic and hence less contrasty, (b) the brightness levels are reduced from the 0.1 to 0.5 millilambert that is attainable with a model made of bare wires, down to the 0.01 to 0.001 millilambert that is forthcoming during clinical fluoroscopy. (Doctor Henny's data for Fig. 4-C indicate that brightnesses of 0.1 to 0.5 millilambert are forthcoming from a Patterson Type B screen when it receives 3.25 to 16.3 r per minute.) The present status of stereo-fluoroscopy might be summarized in these words: Rod vision is simply not competent for stereoscopy. When brightness levels in clinical fluoroscopy reach 100 times their present values, it will be time to build another stereofluoroscope.

In order to apply the knowledge set forth in the graphs of Figs. 15 and 16 to

the problem of clinical fluoroscopy, Doctor Henny measured the brightness of the Type B Patterson screen with the Macbeth illuminometer (see Fig. 13), on a number of different fluoroscopes, using various voltages and current intensities, and with a wide variety of thicknesses of pressdwood phantom. The results are embodied in the graphs of Fig. 7. For the data of Fig. 7-A, a conventional model of fluoroscope was used, in which the target-skin (table top) distance is but 11.2 inches. In contrast to this, the home-made fluoroscope with which the data of Figs. 7-B, 7-C and 7-D were obtained utilizes a target-table top distance of 26 inches. The x-ray tube is cable-connected, oil-insulated, and with the manufacturer's permission we have installed an oil pump, oil reservoir, and flexible neoprene tubings to provide positive circulation of the insulating oil. We are thus able to operate this tube at energy levels as high as 10-15 ma. at 100 kv.p. As the graphs indicate, the brightness levels are higher with this fluoroscope (at a given thickness of the phantom) than with the conventional model, in spite of a lower r-afflux at the patient's skin.

But "visual acuity" and "intensity discrimination" such as the radiologist enjoys while examining films on a good illuminator, would require brightness levels 10,000 to 30,000 times those that obtain in clinical fluoroscopy (Figs. 15 and 16). Even if we compromise on a brightness level as low as 0.1 millilambert, which is 100 to 3,000 times lower than the film reading range, we would be forced to operate our fluoroscopes at currents of 400 to 1,600 ma. (800 to 3,000 r per minute at the patient's skin), an obvious impossibility. In other words, no conceivable change or improvement in the present type of fluoroscope offers the possibility of producing a really satisfactory rise in the brightness level.

Faced with the apparent impossibility of raising the brightness of the present day fluoroscope to a level that would enable it to compete with the roentgenogram, we naturally turn to the question of whether

some intermediate degree of improvement may not be possible. On some of the graphs of Fig. 7 I have indicated the currents that would be required in order to produce brightness levels of 0.01 millilambert, ten times lower than the level referred to in the preceding paragraph (1,000 to 30,000 times lower than the film reading range). I chose the value 0.01 millilambert because that is given by some physiologists as approximately the level at which cone vision begins. As a matter of fact, the most recent work on this subject indicates that the change-over from rod vision (low intensity) to cone vision (high intensity) begins between 0.013 and 0.014 millilambert. Furthermore, the transition is gradual and the arrows which I have placed at the 0.01 millilambert level of Fig. 16 are hardly justified in view of the known facts concerning this transition from scotopic vision (the dark-adapted eye) to photopic vision (the light-adapted eye).

In spite of the fact that a brightness level of 0.01 millilambert is devoid of any spectacular significance, it possesses at least the quality of being attainable under some of the conditions of present day clinical fluoroscopy. At the same time its superiority over the lower levels which we are accustomed to putting up with is very noticeable. I think we can translate this statement into terms of actual experience if we recall the relatively good vision we enjoy on those rare occasions when we fluoroscope the lung fields of an unusually thin patient. Referring again to Fig. 7-A, we note that this graph was obtained with a very ordinary and conventional type of fluoroscope and that a brightness level of 0.01 millilambert was reached when the phantom of pressdwood was thinned down to approximately 8 cm. As reported elsewhere in this paper, a thickness of 8 cm. of pressdwood has approximately the same effect upon the fluoroscopic x-ray beam as a patient's thorax of thickness 16 cm. (a little over 6 inches). In soft tissue regions, elsewhere than over lung fields, a part would have to be a little less than 7

Fig. 13. Photograph of the Macbeth illuminometer as used by Doctor Henny. The pressdwood phantom was 20 cm. thick at the moment the photograph was made. The individual sheets have a thickness of 0.67 cm. Care was taken to insure maintenance of a constant target-screen distance when the thickness of the phantom was varied.

cm. thick in order to absorb the x-ray beam to the same degree as the 8 cm. thickness of pressdwood.

By referring to the third graph of Fig. 7-B (100 kv.p., 5 cm. by 5 cm. field) we note that, owing to improved characteristics and higher voltage, a brightness level of 0.01 millilambert is attainable when the pressdwood phantom is as much as 13 cm. thick, the tube current being 7.4 ma. (27.4 r per minute at the patient's skin). At the present moment additional studies are under way, with a view to learning whether further improvement along the lines suggested by comparison of Figs. 7-A and 7-B may be possible. Actual experience with our home-made biplane fluoroscope suggests that it is, as do also the findings set forth in Fig. 4 and Table I.

Pressdwood is a very convenient material for phantom work. We have no reason to believe that its effective atomic number is different from that of human tissue. Its density is, however, slightly

different than that of the average human abdomen. We carried out a series of measurements of the brightness of the Type B Patterson screen during clinical fluoroscopy of a series of carefully measured abdomens and thoraces. We understand that there are types of pressdwood ("pressdwood" is a trade name for a particular kind of "wall board") which differ in density from the kind we are using. Ours weighs 0.975 gram per cubic centimeter.

There is a good deal of variation among individual human beings. For each centimeter of abdominal thickness, the equivalent thickness of pressdwood varied from 0.95 cm. to 1.35 cm. with an average value of 1.16 cm. For example, the average abdomen measuring 17 cm. thick will have the same effect upon the x-ray beam as 19.8 cm. of the pressdwood.

For each centimeter of thoracic thickness, the equivalent thickness of pressdwood varied from 0.44 cm. to 0.64 cm. with an average value of 0.5 cm. For example, an average thorax measuring 25 cm. in thickness will have the same effect upon the beam as 12.5 cm. of pressdwood.

The technical excellence of the modern American-made "wafer grid" has led us to pay special attention to the possibility of improving fluoroscopic visibility through its use. In Fig. 7-D we present some theoretical and physical evidence, and it must be admitted that, within the range which we have thus far studied, this evidence is against the use of the wafer grid. The decrease of brightness caused by the grid is seen to be approximately equal to that caused by the lowering of the voltage from 80 kv.p. to 60 kv.p. In view of the obvious advantages, to patient and fluoroscopist, of cutting down skin exposure and scattered ray, these findings would appear to favor a lowering of the voltage rather than the application of a wafer grid for the accomplishment of an increase in contrast. There is another side to this question, however. I do not believe that our studies have proceeded far enough to enable us to draw final conclusions. In the first place,

what is true in the range between 60 kv.p. and 100 kv.p. may not apply at voltages of 120 to 140 kv.p. We have not yet satisfied ourselves that a combination of considerably increased voltage and a wafer grid might not bring us much needed improvement. Secondly, there is a definite place for studies of a more empiric type in this field. In addition to further studies with the Macbeth illuminometer, in which the steepness of the absorption curve in pressdwood represents contrast, and brightness is measured in definite units, we plan to carry out investigations with special phantoms designed to reveal empirically the validity of various changes in the technical factors.

A number of investigators have devised phantoms that give more or less significant tests of what might be termed fluoroscopic effectiveness. Burger and Dijk (4, 5, 6) have done particularly good work along these lines. They drilled holes in bakelite, varying the diameters of the holes (for measurement of "visual acuity") and the thickness of the bakelite (for determination of "intensity discrimination," since the thicker the bakelite in which the holes were bored, the greater the "contrast"). The drilled pieces of bakelite were then mounted between other sheets of bakelite and a phantom was thus made up.

We have had some success with pieces of pressdwood (and bakelite, where the texture and strength of the pressdwood were not satisfactory for fabrication). Fig. 14-B shows the appearance of our phantom when it is quite thin. As succeeding layers of pressdwood are added, bringing the brightness down to the levels met with in clinical work, the smaller holes and smaller "buttons," representing, respectively, the negative and positive shadows that are met with clinically, begin to disappear. The largest markings remain visible after all of the smaller ones have disappeared, in the order of their size.

In using such a phantom for comparisons of different fluoroscopes, or different fluoroscopic technics, one sometimes wishes to emphasize the factor of "visual acuity,"
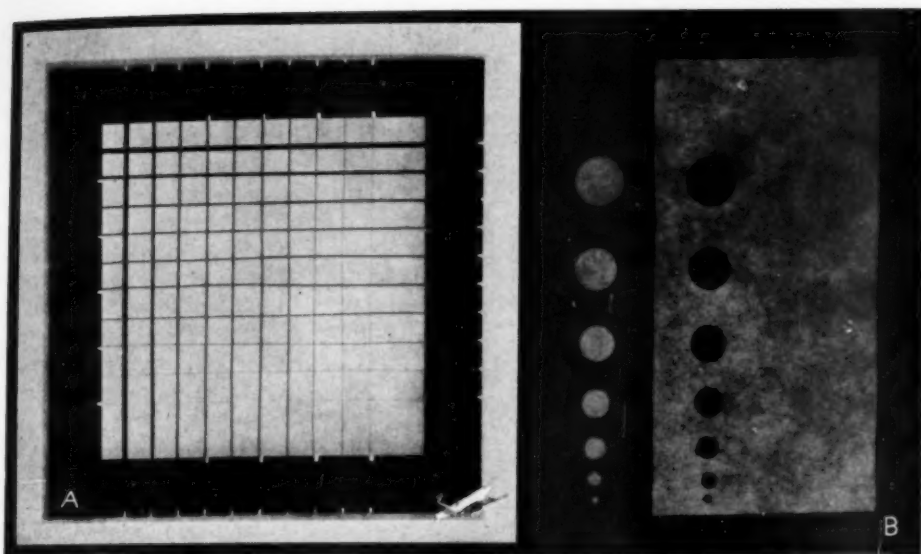
Fig. 14. Many observers have used phantoms for the purpose of evaluating the physiologic limitations of fluoroscopic vision.

A. Ten wires have been stretched in both directions across the 4 inch × 4 inch aperture of a square metal frame, diameter of the wires decreasing progressively from 0.04 to 0.003 inch. With such a wire mesh buried in a paraffin and pressdwood phantom we have demonstrated to ourselves the loss in visual acuity which occurs at low brightness levels. For purposes of comparing different fluoroscopes, such a phantom has the advantage of combining evaluation of inherent unsharpness due to focal spot size, etc., with evaluation of loss of visual acuity at the particular brightness level afforded by the particular fluoroscope under study.

B. "Soft tissues" are more frequently under fluoroscopic scrutiny than metallic particles. The phantom here shown imitates "negative shadows" (holes of varying diameter drilled in a layer of pressdwood, shown on the left) and "positive shadows" (buttons of pressdwood of thickness 0.67 cm., placed within a 5 cm. × 10 cm. × 0.67 cm. air space, shown on the right) at the brightness levels that prevail in clinical fluoroscopy. As in the case of the wire mesh, the studies are carried out with varying thicknesses of pressdwood behind and in front of the "detail."

without regard to the factor of "intensity discrimination." For this purpose we have constructed a composite plate for use with the same pressdwood phantom, in which a series of wires of decreasing diameter are stretched on a metal frame and embedded in paraffin (Fig. 14-A). The 8 wires of each set have the following approximate thickness in inches, from largest to smallest: 0.04, 0.025, 0.016, 0.014, 0.0125, 0.011, 0.009, 0.0065, 0.005, 0.003 (purchased in "American wire gauge" sizes as gauge 18, 22, 26, 27, 28, 29, 31, 33, 36, 40).

Good work is possible with phantoms of both types, especially in the direction of determining limitations, at various patient thicknesses, with different fluoroscopes, or different settings on the same fluoroscope.

Time does not permit an excursion into the chemistry and physics of the fluoroscopic screen. For my bibliography I have selected some items of general interest to the radiologist (25, 32, 33, 50). Attention is called particularly to the contributions of Levy and West, the British originators of the screen we now know as the Patterson Type B.

Doctor Henny has studied the Patterson Type B screen exhaustively and from time to time will doubtless contribute articles on special phases of fluoroscopy. He has shown that fluoroscopic screens, like intensifying screens, possess a "temperature coefficient." With a constant intensity of bombardment by x-rays a Patterson Type B screen gives out more light as its temperature is lowered. Exact measure-
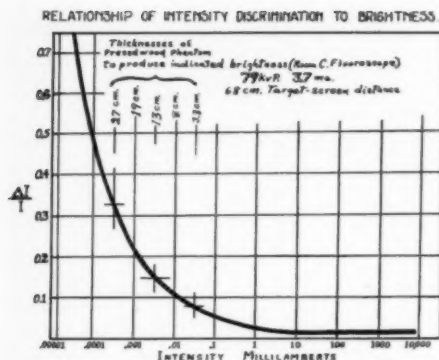
Fig. 15. The curve is from the data of Hecht. Intensity discrimination ($\Delta I/I$) is expressed as the fraction by which a given light intensity must be added to in order for the difference to be visible at that particular brightness level. We have indicated on Doctor Hecht's curve the particular thicknesses of pressdwood phantom that will produce the particular brightness levels we have indicated. Thicknesses of pressdwood phantom can be translated into corresponding thickness of a human abdomen, by applying a factor of 0.86.

ments indicate that the temperature coefficient of the fluoroscopic screen is very much smaller than that of the Par Speed Patterson intensifying screen used with x-ray film. In other words, a lowering of the temperature by any given amount produces a relatively slight increase in the brightness of the fluoroscopic screen but a relatively greater increase of density of an x-ray film exposed between Par Speed intensifying screens. It is obvious that no practical value or clinical importance attaches to this quality of the fluoroscopic screen as at present used. Room temperatures do not vary enough to make any real difference in the performance of screens during clinical fluoroscopy. Results up to date, in the limited range of temperatures at our disposal, have not suggested that the gain in brightness obtainable from operating screens at very low temperatures would be great enough to justify the development of the necessary equipment for maintaining low temperatures at the screen in the presence of tolerable room temperatures.

A very practical result of Doctor Henny's researches is set forth in Fig. 4-C. It appears that within the range of voltages ordinarily used for clinical fluoroscopy the relationship of r per minute to screen brightness is approximately linear. We have reason to believe that with very intense x-ray beams a falling off in brightness will be found. In other words, it appears that regardless of voltage (within ordinary clinical ranges) 0.31 r per minute reaching the screen will produce a brightness of 0.01 millilambert, 0.62 r per minute will produce a brightness of 0.02 millilambert, but 3.1 r per minute will produce slightly less than 0.1 millilambert and 31 r per minute might be expected to produce measurably less than 1.0 millilambert. This is not surprising since there is no reason to believe that fluorescent materials are capable of unlimited increase of their output of fluorescent light with increase of excitation by x-rays or other forms of energy. Doctor Henny is continuing studies and will report later upon the voltage factor outside of the range reported upon here. He has already discovered that the independence of the voltage factor, which is indicated in the graph of Fig. 4-C, is not present as we continue to increase the voltage above the figures ordinarily used in clinical practice.

The important thing about the data of Fig. 4-C is that they make it possible for the clinical fluoroscopist to carry out scientific studies of his own apparatus without the necessity of equipping himself with a Macbeth illuminometer. With a Victoreen thimble chamber and a phantom of pressdwood he can determine the r per minute reaching the screen at various thicknesses of patient. Reference to the data indicated in Fig. 4-C will enable him to translate his figures for r per minute at the screen into terms of brightness in millilamberts. One of the principal aims of this paper is to persuade the clinical fluoroscopist to measure the limitations under which he is working in particular situations. Surely he should know just how poor are his intensity discrimination and visual acuity (a) when fluoroscoping an especially thick abdomen, (b) when fluoroscoping an average abdomen, (c) when fluoroscoping an average thorax, etc. With an r-meter,
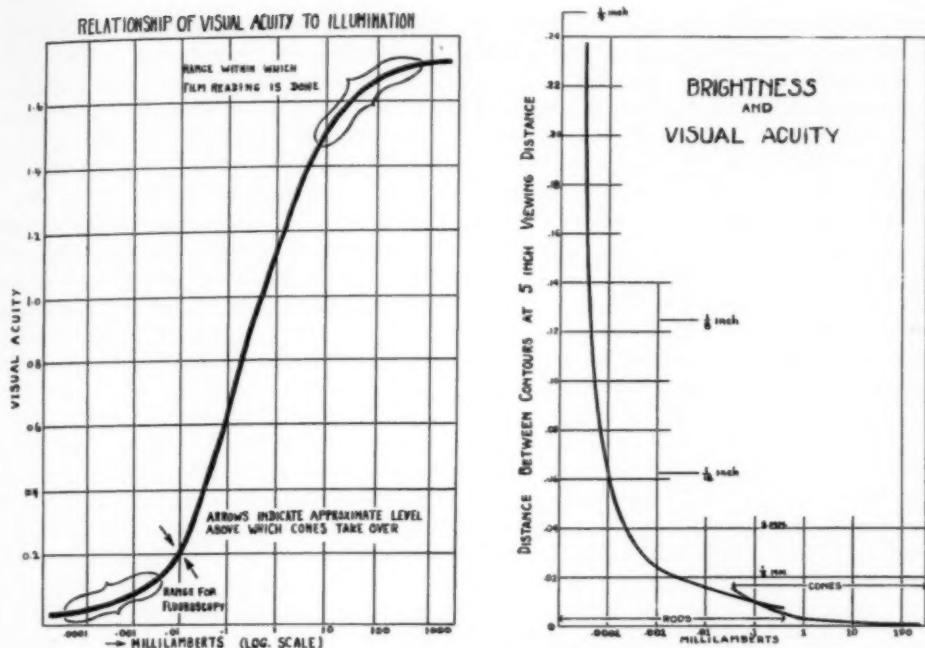
Fig. 16. Visual acuity is defined as the reciprocal of the angular distance which must separate two contours in order that they may be recognized as discrete, the unit of separation being one minute of arc. The graph on the left is after Hecht (20), and we have indicated with brackets the approximate ranges of brightness within which film reading and clinical fluoroscopy ordinarily occur. Our indication (arrows) of the boundary between rod vision (low intensity) and cone vision (high intensity) is open to question because the change-over does not occur suddenly and a far more important feature of retinal physiology is indicated by the steepness of the curve in the range between brightness 1.0 and 0.01 millilambert.

The curve on the right is our own, but is based entirely upon Hecht's graph of visual acuity at various brightnesses of green light (see Fig. 25, page 271 of Hecht, 21). Instead of plotting "visual acuity" we have based our graph directly on the "separation between contours" upon which the definition of visual acuity depends.

a pressdwood phantom, the data of Fig. 4-C, and reference to the findings of the biophysicists and physiologists as summarized in Figs. 15 and 16, he can give meaning to the situation that confronts him in the fluoroscopic room.

The clinical radiologist who carries out the above suggestions will gain a new insight into one of the most important elements in his armamentarium, fluoroscopy. He will be surprised at the extraordinary degree to which the fluoroscopic x-ray beam is absorbed in the patient. With the average fluoroscope of conventional design and modern manufacture, an abdomen 10 inches thick will permit as little as one part in 2,000 of the incident beam to reach the screen. In other words, in order for 0.015 r per minute to reach the screen (producing

a brightness of approximately 0.0005 millilambert), the incident beam at the patient's skin must have an intensity of the order of 30 r per minute.

The modern fluoroscopic screen provides a wealth of detail and excellent contrast. When photographed with precision, it yields an amazing result, amazing chiefly because we have tended to think of the inadequacy of clinical fluoroscopy as in some way inherent in the apparatus. Actually it has always been inherent in the functional limitations of the human retina.

Suppose that the detail and contrast that are present on the fluoroscopic screen were as visible to the radiologist as the images on good roentgen films. Under such circumstances a fluoroscopic study would be tantamount to viewing thousands

of excellent roentgenograms in cinematographic sequence—roentgenograms made at all possible phases of functional movement and in any or all selected angles of projection. The present day x-ray film would be unable to compete with such a device and one cannot but believe that normal and morbid physiology would become as much the province of the radiologist as anatomy and gross pathology already are.

From a consideration of retinal physiology (*vide supra*) it is apparent that what is needed for the realization of such a revolutionary change in clinical fluoroscopy is not simply a 10-fold or 100-fold increase of brightness. An increase of the order of 1,000-fold would be required. What is the likelihood that such may be forthcoming?

In my own opinion it is just around the corner and when it comes it will put medicine and radiology through another revolution, not very different from that which followed the advent of roentgenography and present-day fluoroscopy at the turn of the century. That it is on the way is attested to by the measure of human achievement recently attained in the fields of the electron microscope and the television transmitter.

A few months ago it was my privilege to view the fluoroscopic screen of the R.C.A. electron microscope in Camden, New Jersey (35). Magnetic lenses focus electron beams exactly as glass lenses focus beams of light. The electrons used in the R.C.A. electron microscope have frequency characteristics that make them equivalent to photons of wavelength approximately 1,000 times shorter than the wavelength of visible light. This gives it a greater resolving power, and magnifications as high as one hundred thousand have been accomplished by adding photographic enlargement to the magnification obtained directly in the microscope itself.

In the electron microscope (Fig. 18), the electron beam which originates from the "electron gun" is converged by a magnetic lens coil corresponding to the condensing lens in an optical microscope. The condensed electron beam is focused upon the specimen that is under observation. The rays of electrons which emerge from the specimen in the direction of the observer are now focused by other magnetic lenses, so as to form the highly magnified image. This image is made visible by causing it to strike a fluorescent screen. (Even when the objective is a photomicrographic film, the focusing and field selection are accomplished with the fluorescent screen.) It seems perfectly obvious to me that similar principles can be invoked for fluoroscopy. This has already been done in the case of television.

In a television camera the light from the camera lens is focused upon a sensitized surface which gives off electrons in proportion to the intensity of the impinging light. The electrons thus given off form what is technically known as an electron image. Were we to allow an x-ray beam to impinge upon the same sensitized surface, instead of the focused light from the photographic lens, we would also obtain an electron image. The electron image of the "televisor" is focused by magnetic lenses and the next step, in the case of television, is the scanning of the electron image. In the carrying out of this procedure of scanning, all but one-hundredth of one per cent of the energy in the electron image is discarded, for at any given moment the only electrons that are utilized are those which enter an extremely small aperture, the area of which is certainly no greater than one part in several thousand relative to the total cross-section of the electron beam. The reason that this minute fraction of the total energy is adequate for purposes of television transmission is that, after the electron image has been formed by the action of radiation upon the sensitized surface, the electrons are subjected to a voltage differential which accelerates them and, by the time they reach the opposite end of the televisor tube, they contain a great deal more energy than they contained when they started. The principle is the same as that in the hot cathode x-ray tube, in which the energy of the electron beam that bombards the focal spot is due to the difference of

potential between the cathode and anode.

When we begin to apply the principles of television and the electron microscope to the problem of fluoroscopy, we will not discard 99.9 per cent or more of the energy in the electron image beam, because we will not be under the necessity of scanning the image. We have but to focus it on a fluorescent screen at the opposite end of the accelerator tube from the sensitized plate where the electron image was formed. Whether or not we will make use of the ability to alter the size of the image, I do not know, but I presume that we may sometimes contrive to increase our brightness levels by reducing the image to dimensions considerably smaller than those at the original sensitized surface. At other times we may wish to produce varying degrees of enlargement of the image. It is conceivable that this may be accomplished simply by the operation of a current regulator in the circuit that supplies the magnetic coils of the lens system.

I cannot refrain from mentioning some economic facts that may be pertinent. A batch of 5 electron microscopes has been produced at the Camden works of the R.C.A. The list price is $9,400. The device is quite elaborate, and under all of the circumstances a price of $9,400 is remarkably low. Nevertheless, if these microscopes were produced in quantities the price would be a great deal lower. The most expensive single feature of such a device, as I see it, would be the stabilizer for the magnetic lens current supply and voltage supply for the accelerator tube. In the R.C.A. electron microscope the regulation of the voltages and current is so important that the supply must be stabilized to within approximately one part in sixty thousand.

When these principles have been harnessed for the use of the fluoroscopist, he will have a very different method from the one now available. Our interest in the roentgenogram will dwindle. There is much talk of the "value of a permanent record" and we have got into the habit of thinking that such permanent records as we obtain on roentgenograms are important. As a matter of fact, when you and I go to see our family doctor or become patients of famous internists, we are not concerned over the fact that photographic recording of the findings is not a part of his armamentarium. The fluoroscopist will need to be highly trained. (Perhaps the radiologist will come back into his own when the records cease to be bandied about as x-ray films are today.) When he is studying a patient he will have the equivalent of literally thousands of roentgenograms, because he will be able to rotate the patient into various positions and nothing that can now be shown on roentgenograms will escape his powers of observation. Does anyone believe that such an outcome is impossible of attainment? Surely no one, in view of what has been accomplished in these neighboring fields. Dr. Irving Langmuir, of the General Electric Research Laboratories in Schenectady, has already made a beginning (see Fig. 18).[6]

Doctor Langmuir's patent was granted nearly three years ago. Judging from the usual experience, his application must have been filed about two years before the patent was granted. In view of the achievements of the physicists and engineers in the R.C.A. Victor laboratories at Camden, and in other research laboratories where successful electron microscopes have been built, it is a little hard to understand the delay in the creation of a practical device for the acceleration of electrons in an electron image of fluoroscopic origin. Perhaps what is needed is a realization by the physicists and engineers of the great need for

[6] On Jan. 20, 1942, U. S. Patent 2,270,373, covering a "Neutron Image Converter," was granted to Hartmut I. Kallmann of Berlin-Charlottenburg and Ernst Kuhn of Berlin, Germany, assigned by them to I. G. Farbenindustrie Aktiengesellschaft, of Frankfurt am Main. The diagrams which accompanied the application indicate a beam of neutrons striking a sensitive surface after traversing a human body in the manner of a fluoroscopic x-ray beam. "Charged particles or electrons" which emanate from the sensitive surface or "neutron reactive layer" are then accelerated by an electrostatic field and focused on a fluorescent screen by either an electrostatic lens or an electromagnetic lens. (A "second stage" of amplification by electron acceleration is indicated on the diagrams. This second stage appears to be identical with the device of Langmuir as shown in Fig. 18.)
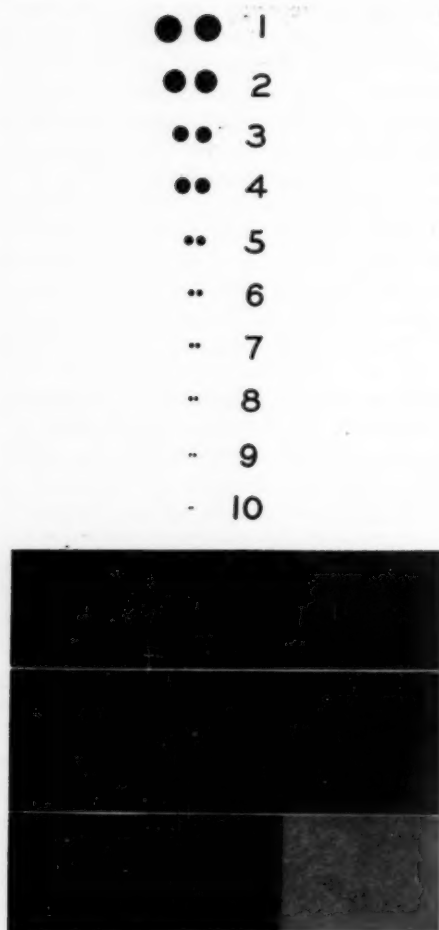
Fig. 17. Top. Doctor Henny's "Adaptometer" based upon visual acuity. As the dots decrease in size, their separations are proportionately decreased. For clinical use a positive transparency of these dots, on photographic film, is placed on top of lead glass shield of fluoroscope, there being a filter of 3 mm. Cu on table top below illuminated section of screen. Such a filter (3 mm. Cu) cuts the brightness level of the fluoroscopic screen to that which obtains during fluoroscopy of the abdomen of a heavy patient. By observing how far down the series of numbered dots he can discern separation, the fluoroscopist can measure his degree of dark adaptation in terms of visual acuity.

Bottom. The author's "Adaptometer" based upon intensity discrimination. High degrees of contrast are present in the lower row of densities while the upper row exhibits low degrees of contrast. By observing thickness of filter (wedge or stepladder) which can be introduced between fluoroscopic shutter opening and screen without rendering a given contrast (intensity difference) invisible, the fluoroscopist obtains a measure of his dark adaptation.

brighter fluoroscopic images and the great advantage to humanity which their arrival would entail. After all, it was easy for the physicist to realize that greater degrees of magnification than were possible with the optical microscope would be of extreme value to biologists and physicists. In the case of the fluoroscope it has not been so easy to outline the need, for only through such a theoretical approach as the present one could the possibility be realized.

One further point should be made about the potentialities of electron acceleration for the amplification of the fluoroscopic image. Without knowing just how great the resultant amplification will be, it is nevertheless possible to point out that it need not be wholly utilized for increasing the brightness of the fluoroscopic screen. A part could be used for decrease of the intensity of the fluoroscopic x-ray beam. In my opinion it is within the realm of possibility that very useful degrees of increase in the brightness level of the screen may be accompanied by a substantial reduction in the r per minute at the patient's skin.

However close the goal of a thousand-fold increase of brightness of the fluoroscopic screen may be, and I suspect that it is closer than appears on the surface, we must nevertheless continue for the present to cope with the inherent limitations of present day fluoroscopy. While we are waiting for the arrival of something better, what is to be done about it? I would like to close in this vein.

1. In the first place, as never before the radiologist should lay aside guess work and apply himself to a more scientific appraisal of his fluoroscopic technic. Instead of carelessly neglecting the discipline of adequate dark adaptation, as some have done, or relying entirely upon the clock, as some others have done (I include myself), it would seem advisable for him to test his dark adaptation, from time to time if not on each occasion. Some years ago Doctor Newell and I had a device in our fluoroscopic room which we thought was quite satisfactory for an appraisal of the degree of dark adaptation. It was composed of

tiny samples of calcium tungstate mixed with radium, and by diminutions in the size of the blotch of fluorescent source, as well as by dilutions of the same, succeeding blotches became less and less visible to the partially adapted eye. One counted one-self as fully dark-adapted when one could see all of these blotches of faint luminosity down to the smallest and weakest. This was of course a test that depended upon the threshold intensity rather than on visual acuity or intensity discrimination. Doctor Henny has introduced me to a quite different solution to this problem and one which I feel has practical value for you. In Fig. 17 we see a photograph of a series of black dots, the diameters and separations of which descend as one follows the numbers from 1 to 10. In the order of descending size the diameters are, in millimeters, 8, 6.5, 4.5, 4.4, 2.5, 1.8, 1.3, 1.0, 0.8, 0.5. The spaces between the dots are, in the same order, 4, 2.8, 2.0, 1.5, 1.0, 0.8, 0.4, 0.4, 0.3, 0.1. You will note that the order of change of size and the order of change of spacing are not entirely consistent. The original work was done on a drawing board and the measurements I am giving you are some direct measurements on the photographic transparency which we use in the fluoroscopic room for determining the degree of dark adaptation. The technic is as follows.

The fluoroscope is operated at a routine setting that can readily be returned to. A 3 mm. copper filter is placed on the horizontal fluoroscopic table and a narrow beam of x-rays is directed through that filter onto the screen. The screen is elevated a standard distance, preferably about 12 inches, above the table top. The transparency film upon which the dots of Fig. 17 have been recorded, photographically, is placed over the small area of screen illumination and the fluoroscopist decides how many pairs of dots he can see as discrete. If under the above circumstances his eyes are well adapted he will find that the dots are separated down to and including No. 5 or No. 6, and that the remaining pairs of dots appear as though merged into single

blotches. Incidentally, the level of brightness obtained through the 3 mm. copper filter with the technic as outlined is approximately equivalent to what would be obtained with 10 inches of pressdwood or about 9 inches of abdominal thickness. It is obvious that Doctor Henny's adaptometer, being based upon visual acuity, is more suited to the needs of the fluoroscopist than tests of threshold intensity.

More recently we have been experimenting with an adaptometer for the clinical fluoroscopist based upon intensity discrimination instead of upon visual acuity. Reference to Figs. 15 and 16 has suggested to us that the deterioration of intensity discrimination at low brightness levels is more important to the clinical fluoroscopist than is loss of visual acuity. At the bottom of Fig. 17 is shown a photograph of our latest adaptometer transparency, a roentgenogram of a "stepladder" of absorbent material. We have used aluminum. Ours is but a beginning and could easily be improved upon by any of you. The thicknesses of aluminum used for this present film were as follows. For the central 2 cm. × 2 cm. field an aluminum thickness of 20 mm. was used. The 2 cm. × 2 cm. square fields in the top row were exposed through 19, 20, and 21 mm., respectively. The square fields in the bottom row were exposed through 17, 20 and 23 mm., respectively. With such a stepladder transparency the procedure is as follows. The arrangement of fluoroscopic apparatus, copper filter, and adaptometer transparency is much as it was for Doctor Henny's visual acuity method. The shutters are arranged so that an area of fluoroscopic screen about 2 inches square is illuminated. The stepladder transparency is centered over this area. A "stepladder" or "wedge" of copper is interposed in the beam at the table top and the measure of adaptation is the thickness of copper at which the intensity discrimination for the smaller density steps is barely adequate. If the device should come into general use, it would doubtless be possible to mechanize it in some standardized form. As stated above,

it would be easy to improve upon this transparency and we have not yet satisfied ourselves that our approach is the best from a practical standpoint. The reason for presenting it at this time is to emphasize the importance to the fluoroscopist of the attainment of the best possible degree of intensity discrimination before considering himself as satisfactorily dark-adapted.

2. In the second place, after he has paid due attention to his dark adaptation, the radiologist should go to the pains of informing himself as to the degrees of limitation which are being imposed upon his visual apparatus at any given moment. Why should he continue to view the fluoroscopic screen and report presence or absence of certain findings without knowing just what is the measure of his disability? By means of an r-meter and Doctor Henny's figures on response of the Type B screen (Fig. 4-C), he can know fairly closely the brightness level at which he is working. After he has made the r-meter determinations with a pressdwood phantom or with a number of different thicknesses of patients, he can come fairly close to the facts merely by using a tape measure on his patient. He can then refer to such data as those of Figs. 15 and 16 in order to know how bad is his intensity discrimination or his visual acuity under the particular circumstances.

3. In the third place, in those instances where visual acuity is of prime importance and intensity discrimination of secondary concern (e.g., in the case of a minute metallic foreign body) he can aid himself measurably by wearing lenses of 3 to 6 diopters, which will permit him to increase the area of retina upon which the image is focused. In other words, if he is limited to a visual acuity of 0.06 by the particular brightness level at which he is working, he will know that a separation between two contours of less than 0.24 inches will be invisible if his eye is 5 inches or more from the screen surface. By bringing his eye much closer, the discernible details can be correspondingly smaller since the retinal arc is made larger by that maneuver. In the

5-, 10-, and 25-cent stores we find satisfactory lenses for this work. I have some here in my hand which cost me 25 cents and which are definitely of value under the circumstances I have just outlined. That such lenses are not of greater usefulness in routine fluoroscopic work is due to the fact which I have tried to emphasize this evening: that loss of intensity discrimination is more important than loss of visual acuity in the average fluoroscopic procedure.

4. Some of the fluoroscopes in use today are inferior and should be modified. Target-screen distances should never be less than 18 inches and we are quite sure that 26 inches, fairly close to the maximum that is permitted by even the most convenient of tilt-tables, is an improvement over any shorter distance. Cable-connected tubes are to be preferred to other types because they permit a wider range of voltage and current variation than is usually possible with oil-immersed units.

The selection of the tube is important. In the present state of the art, none of the available tubes is above criticism. The recently developed tube of the U. S. Army Field Unit is ideally suited to the job for which it was designed, but its limitation of 100 kv.p. precludes its adoption as the final solution of our fluoroscopic x-ray tube problem. Subject to review in the light of additional knowledge and experience, we submit the following as the desirable, if not essential, features of a tube for clinical fluoroscopy.

A. It should be capable of operating at 120 kv.p. on full-wave, 4-valve-rectified transformer. B. It should be of the shockproof, cable-connected, oil-insulated type. C. It should be provided with some positive method of cooling the housing, either by air blast, as in the case of the U. S. Army Field Unit tube, or by circulating water in water jacket or cooling coils. (The forced-air-blast method gives evidence of adequacy and may make the complications of water-cooling unnecessary.) D. The anode stem should be hollow and should be provided with some method for

forcing cool oil against the copper as near as possible to the focal spot.[7]

Another feature of the average fluoroscope which needs improvement is its lack of a booster or high-energy setting to supplement the routine setting. It is extremely desirable, both from the standpoint of better fluoroscopic vision and from the standpoint of protection, that every fluoroscope should have at least two separate settings, one to be controlled by the foot switch, at an energy level which is satisfactory for prolonged observations but is preferably kept as low as feasible, the other to be at as high a level as can be permitted in view of all of the limitations, operated by a push button and so arranged that upon removal of the fluoroscopist's finger pressure the energy level returns to the lower (foot switch) value. We have added such boosters to most of our fluoroscopic beams and after several years of experience we are convinced of the importance of this arrangement.

5. Finally, it is high time that we took advantage of new knowledge concerning light adaptation and dark adaptation, knowledge that has recently been gained through the important studies of physiologists in connection with night flying. It is obvious that the effectiveness of the British night fighter pilot depends upon his being completely dark-adapted when he takes to the air to combat the Nazi scourge. The investigations which this necessity has instigated have emphasized the importance of some things which are

[7] Many present day tubes of the oil-insulated, cable-connected type are provided with positive circulation of the insulating oil, which conducts heat quite rapidly from the anode to the housing. The U. S. Army Field Unit tube is provided with a special motor-driven "impeller" for this purpose, but even without such a device a very effective circulation of the oil takes place through electrostatic-charge convection when the voltage applied to the terminals of the tube is rectified. (In the case of alternating potentials, connected for self-rectified operation, this electrostatic-charge convection is absent.) But the heat from the focal spot must be conducted along the anode stem before it can reach the circulating oil, and maximal power inputs, much needed if we are to take full advantage of the telefluoroscopic principle, will not be possible in the absence of some such arrangement for introducing the cooling fluid into a hollow anode stem.
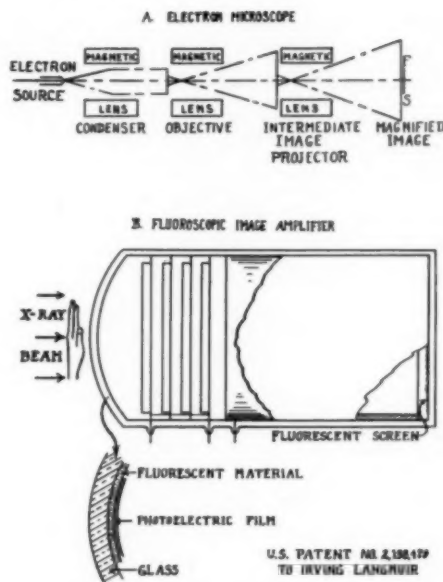

Fig. 18. Fluoroscopic screen images are technically equal in "sharpness" and "contrast" to images on x-ray films, but limitations of retinal physiology (loss of visual acuity and intensity discrimination at low brightness levels) render the available sharpness and contrast more or less invisible. From this it follows that the one great need for an improvement in clinical fluoroscopy is an increase of the brightness level of the order of 1,000-fold.

In the electron microscope the electron image possesses spectacularly good resolution even after magnification to several thousand diameters. Such magnification necessarily produces a corresponding decrease of intensity, yet reasonably high brightness levels are obtained at the fluoroscopic screen (used for field finding and focusing) of the electron microscope. This is because the available energy in the electron image is tremendously amplified by electrostatic acceleration of the electrons during their transit through the vacuum chamber. A similar maintenance of resolution, by means of magnetic lenses, is obtained in the scanning tube of a television transmitter. Ordinary light is focused upon a "photo-electric film" by the lens of the television camera. An "electron image" is thus produced and the electrons which make up this image are then accelerated by an electrostatic field.

At (B) is pictured the fluoroscopic image amplifier of Langmuir. Doubtless some such system will be successfully adapted to the problem of clinical fluoroscopy, with revolutionary effects upon the practice of medicine.

disclosed in Fig. 12 and hinted at in Fig. 10-C. Red light at wavelengths longer than 6,700 Å. apparently does not bleach visual purple. At any rate, even high intensities of such deep red light do not cut

down rod sensitivity. We have recently begun some work which may lead to a scientific solution of the problem of how to carry on between fluoroscopies while at the same time retaining a high degree of dark adaptation. In the meantime, a partial solution of this problem is available to anyone. You have all noticed how readily we prepare our eyes for fluoroscopy if we have been subjected to artificial light only. Even so-called "white light" from artificial sources is so weak in the more actinic rays toward the blue end of the spectrum that it partakes in minor degree of the nature of the deep red light we have been discussing. Whether or not we find a method which completely preserves rod vision, certainly we can shorten the time required for adequate dark adaptation by excluding daylight from our work rooms. At Temple University Hospital we recently began a survey of various colors of artificial illumination which are relatively beneficial to dark adaptation but are at the same time not unpleasant to work in. In these days of air-conditioning and well developed artificial ventilation, there is no difficulty in closing up windows and shielding doors so that daylight is excluded and we may decide to convert our entire department along the above lines. Preliminary tests show that a very few minutes of dark adaptation will accomplish as much as thirty or forty minutes ordinarily accomplish, if the observer has been protected from the more actinic wavelengths for a number of hours prior to entering the fluoroscopic room. It goes without saying that our researches in this direction include studies of possible colors and intensities for use on film illuminators.

In closing I need hardly point out to you that when I accepted President Wasson's assignment nearly a year ago, I did not even know enough about fluoroscopy to know that I did not know. Doubtless my ignorance is still abysmal and will appear so to me from the vantage point of another year or two. In the meantime I can honestly say that whether or not I have brought something of interest or value to

you, I certainly have enjoyed the stimulation which this assignment has given me. In particular, it has renewed my enthusiasm for the physicists. Years ago we learned to rely upon them in matters of therapy and x-ray protection. More recently, physicists whose duties in therapy were not so arduous as to keep them cornered have brought us much help in the field of roentgenography. During the past year I have been a witness to another example of how helpful the physicist can be, for my own physicist, Dr. George C. Henny, has been my mentor in the work I have presented this evening. Only by reiterating this fact can I avoid the sin of taking undue credit for myself.

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The Inception and Development of Fluoroscopy: The Influence of Carman on Its Status in America*

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Russell Carman was ever a protagonist for fluoroscopy in roentgen diagnosis both by word and deed. Throughout the major portion of his medical life, his published observations were based in generous measure on his findings by fluoroscopic screen, notably with reference to alimentary anomaly and disease. As he preached so did he practise. A fluoroscopic demonstration by him was one of the Rochesterian lodestones that have for so long projected their magnetic attraction into all corners of a medical world that delights to learn by observation. To sit by his side, facing the pale glow of his fluoroscopic screen, was to witness the exhibition of a skill that could result only from his deep love of the work as well as from his implicit faith in it. In Carman's hands, the practice of fluoroscopy involved the exercise of a sympathetic individualism that would be quite lost amid the multipersonal technicalities of mere radiography. What better proof of this than his memorable habit of preliminary kindly inquiry as to the habitation, home-life, and little predilections of an agitated patient who had entered for the first time the Cimmerian atmosphere of the screening-room, but who, from that moment, was disturbed no longer and whose upper digestive tract forthwith shared his tranquillity? It is an *art* thus to mitigate, with the warmth of sympathy, the cold impersonality of an applied science—and in the doubtful gloom of that chamber, in front of an invalid soothed and calmed without having even seen clearly his benignant face, sat an artist of the first magnitude!

Perhaps, then, it were not inappropriate, as the second lecture to be given in respectful commemoration of the life of this remarkable man, briefly to consider the history of the diagnostic adjuvant by which he laid such great store, which he was ever ready stoutly to defend, the elaboration and expansion of which his loyal support so greatly aided, and through which he served humanity so devotedly and so effectively.

* * *

It is to the gifted Irish Cantabrigian, Sir George Gabriel Stokes, of course, that we are indebted for the term *fluorescence* as well as for the greater part of our present knowledge of this subject, but we should not allow to escape from our memory the name of the discoverer of this beautiful phenomenon as well as of the principle of lenticular stereoscopy and of the kaleidoscope, the versatile Sir David Brewster, Scottish theologian, natural philosopher, biographer and editor. Well-known are his observations on the behavior of a beam of solar light on passing, after condensation, through a solution of chlorophyll. The sub-fluid course of this beam was revealed to him as a ray of brilliant crimson. Investigating further, he observed varied color-change, produced in the same manner, in connection with other vegetable solutions, with certain essential oils and also with some crystals, among them native calcic fluoride, or fluor-spar. The results of this initial experimentation were communicated by him to the Royal Society of Edinburgh in 1833. Calling the phenomenon *internal dispersion*, Brewster believed it due to the scattering of light by colored particles held in suspension. Somewhat later, Sir John Herschel observed that a beam of solar light, striking a solution of quinin sulphate, became "epipolized," as he called it; it assumed a blue

color in a stratum just beneath the surface of the fluid at which the beam entered. Beneath this stratum the beam was not changed as to color or strength, nor could it be recolored by passing it through a second solution of quinin sulphate.

As much later as 1852, it remained for Stokes, using at first a solution of quinin sulphate, to show that the effect was due, not to the scattering of light by suspended particles, but to the fact that the dispersed beam actually differed in refrangibility from the light which excited it. On this basis, he called the phenomenon for a time *true internal dispersion*, as opposed to the theory of light scattering, which he considered under the name of *false internal dispersion*. Ultimately dissatisfied with this definition, he adopted the term *fluorescence*. The outcome of Stokes' prolonged experimentation is now common knowledge of the physical laboratory; it resulted in the law that the fluorescent light is of lower refrangibility, of greater wavelength, than the light exciting it, or, as the electrophysicist Hammer[10] many years later aptly observed: "In electrical parlance, a fluorescent substance might be termed a step-down transformer for light-waves." Stokes' Law did not apply to all substances, as he believed, for it was later shown that there are more than one kind of fluorescence. Of the scores of substances from the mineral and vegetable kingdoms that had contributed to the researches of Brewster, Herschel, Stokes, Pierre, Lommel, Voight and others, the humble group of the platino-cyanids alone were touched by the bright wand of Destiny, and down through the long years of laboratory experimentation and lecture-room demonstration the platino-cyanid of barium found its solitary way to that memorable table in one of the smaller rooms of the Physical Institute of the University of Würzburg. Heretofore, the phenomenon of fluorescence was an instrument of pure science, largely utilized to illustrate the laws of reflection and refraction. The instant a bit of paper coated with this salt was seen to glow in complete darkness, for no appar-

ent reason at the moment, by the quick eye of Professor Röntgen, rays of a wave-length otherwise invisible to the eye were revealed, and at the later moment when Röntgen first interposed an object between this fluorescent paper and the Hittorf-Crookes tube, encased in black paper, with which he was just then working, fluoroscopy as a practically living thing was born.

Röntgen, according to the story that has been retold so vividly of late,[9] had been engaged in repeating Lenard's experiments with cathode rays, and had covered a Lenard tube with black paper to observe their fluorescence through a window in the tube. He then continued his work with a Hittorf-Crookes discharge tube. The barium platino-cyanid paper was at hand because, as he later told Mackenzie-Davidson, this salt was in common use among German physicists to reveal the invisible portions of the spectrum. Röntgen's use of it in his succeeding observations, once its behavior in the presence of the covered tube was noted, was mentioned by him in his classic *Preliminary Communication*. This resulted in its almost universal adoption as the medium of choice in the earliest days of fluoroscopic investigation. In its employment the method of Röntgen was generally followed, except that there was a widespread effort to obviate the darkened chamber enclosing the observer. Curiously enough, in their enthusiasm over their specialized devices to simplify the scrutiny of the fluorescent screen by merely shading the eyes, many physicists almost created a popular conviction that they had produced something involving an entirely new application of the principle of x-radiation. This sentiment was perhaps strengthened by the fact that each was quick to give his device a specific name. Thus, as the painstaking historian Glasser observes, the "cryptoscope" of the Italian physicist Salvioni,[13] of Perugia, "caused almost as much enthusiasm . . . as was caused by the announcement of the discovery of the roentgen rays." Yet it would be unjust to the spirit of Salvioni to assume that he sought

for himself one jot or whit of such credit, unthinkingly misplaced. His instrument, the first of its kind, was tubular in form. One end was closed by a sheet of black paper upon which, for temporary lack of barium platino-cyanid, was spread a layer of fish-glue and calcium sulphid. Within the tube, near the opposite end, was fixed a lens giving a clear image of the luminescent paper, which must have been so largely phosphorescent. Concerning this device, Salvioni was modesty itself. "In this," he says in his description, "there is, of course, nothing new which could not have been deduced from the original experiments of Röntgen; the novelty, if indeed it is so, consists merely in making use of the known facts to design the arrangement. It seems to me that, in a more perfected form, it might be of extensive use in surgical and medical science. The sulphide of calcium may be replaced with advantage by the cyanide of barium and platinum. . . ."

Salvioni's term "cryptoscope" was not infrequently applied to any form of hooded screen for some years following 1896. One well remembers its occasional usage in our country even after the period of Edison's exhaustive investigations of that year. William Rollins very frequently made use of the term. Close on the heels of Salvioni's work came reports of other forms of hooded fluoroscopic screens. The instruments of Spies and E. P. Thompson were truncated cones instead of being cylindrical. Thompson, not to be outdone in the way of especial designation, called his device a "kinetoskotoscope." The apparatus of Magie, of Princeton University, was closely contemporaneous with that of Salvioni; likewise it was tubular in form. It was known as a "sciascope." The devices of John MacIntyre and of Edison were truncated pyramids; it was this form that prevailed in the later construction of the hooded fluoroscopic screen, through the romantic and tragical days of its rise, decline and fall.

Throughout what may be called the pre-Edisonian era, all designs of fluoroscopic apparatus involved the use of the platino-

cyanid of barium. Salvioni mentions its desirability and undoubtedly would have employed it in his first device had circumstances permitted. An early exception was the screen of Herbert Jackson, of Kings College, London, upon which potassium platino-cyanid was the salt employed.

From Mr. Edison's well-known experiments of 1896 with a tremendous number of crystalline substances came the discovery of a fluorescent salt which in many ways, although not in all, was superior to the cyanid; it was not so susceptible to atmospheric conditions but it was sufficiently phosphorescent to give it an appreciable "lag," but for fluoroscopic purposes this was not a great fault. With this substance, calcic tungstate in a finely divided form, he coated a plane support and covered this screen with a hood in the shape of a truncated pyramid to exclude daylight, placing an aperture formed for the eyes at the line of truncation and a supporting handle on one of the sides of the pyramid. Edison called his device a "fluoroscope," but in declaring that he invented the fluoroscope many historical writers have created the false impression that he was the discoverer of the initial practical means by which invisible x-rays are changed to visible light rays. This discovery, of course, was Röntgen's, but to Edison is to be given the credit of the discovery of the tungstate of calcium as a fluorescent material of peculiar qualities of excellence.

The use of the hooded screen had, as its earliest purpose the lecture-room or laboratory identification of the presence of roentgen rays in the general study of radiation; later, it was frequently used in demonstrations that were held under conditions of a character less academic, many of which were patterned, on a smaller scale, after Edison's historic fluoroscopic exhibition of 1896, given in conjunction with the exposition of the National Electric Light Association at the Grand Central Palace, New York. Also, the hooded screen was used as a medium of gauge to test the quality of x-emanation during the course of evacuation

of Crookes tubes or of radiographic ex-
posures—a pernicious practice to which is
appended one of the sad phases of radio-
logic history. Finally, as the petals of the
flower of evolution slowly opened, the
fluorescent screen of the physicist became
the *fluoroscopic* screen of the clinician, in
form both open and hooded, and the path
was cleared for its steady advance in diag-
nostic usefulness.

There can be no question that the earli-
est medical attitude toward fluoroscopy, or
roentgenoscopy, was in great measure in-
fluenced by the contemporaneous opinion
of the physical or engineering laboratory.
In view of the practical outcome of his in-
tensive labor in the matter of fluorescent
substances, Mr. Edison was enthusiastic,
even arbitrarily so, over the future of his
"fluoroscope." Said he, as reported[8] in the
American Journal of Photography of April,
1896, ". . . There is no occasion to take
photographs, shadowgraphs or radiographs.
I stopped that long ago. You can see for
yourself, the fluoroscope does the work in a
moment." One cannot but wonder at the
effect on the development of radiology had
he indeed "stopped" roentgenography!
No doubt he had in mind, in this connec-
tion, the problems of minor traumatic sur-
gery which, at an earlier day, usually pre-
sented themselves to non-medical thought
where the roentgen rays were concerned,
but Edison's every pronouncement at-
tracted wide attention and one is con-
strained to feel that his attitude had much
to do with the intensity of the "first fluoro-
scopic era," as it may be called, that ob-
tained from 1896 to 1900. There is but
little doubt, also, that the demand upon
the early roentgen worker of this period
for the "quick" use of the fluoroscope
(which, mind you, was still largely the
hooded screen) in emergency surgery or in
the more gross pathology of the thorax,
was at least one of the factors, albeit a les-
ser one, making for the wide incidence of
radiation-dermatitis during those years.
"All we need here is the fluoroscope—that
will tell us all we want" are words that still
ring in the ear of the medical pioneer in

radiology, and, since the use of this instru-
ment alone was thus preordained, the en-
suing scrutiny was usually prolonged. In
this way the seed of irreparable damage was
frequently sown. The martyred pioneer
Kassabian, in somewhat rueful retrospec-
tion of the conditions of the first fluoro-
scopic era that led to his plight, remarked
of the ardent souls who thus importuned
him: "I would have stopped the [use of
the] fluoroscope then, but they would not
let me." However, the bearing of the
fluoroscope on the history of the martyrs to
roentgenology is a matter of another writ-
ing, and by no means germane to our con-
sideration of today.

Francis Williams of Boston, constantly
aided by his *fidus Achates*, William Rollins,
labored diligently throughout these four in-
tensive "fluoroscopic" years. Being an
internist by medical training and for many
years an attending physician to his hos-
pital, he paid little attention, when once
launched upon his new-found work with
x-rays, to the clamor for the impromptu use
of the fluoroscope in minor surgical prob-
lems. Williams and Rollins, by nature,
were to hasty and incomplete procedure as
oil, by nature, is to water. This was the
existing equation, at the Boston City Hos-
pital, with reference to the first importu-
nate demands for immediate resort to the
fluoroscope in almost any clinical situa-
tion. But the rational applications of the
fluoroscopic screen attracted Williams at
once, and some months later he wrote:
". . . it was the confidence I had in the
possibilities of the fluoroscope to assist in
the diagnosis of diseases of the lungs and
heart that led me to begin and develop
this method of examination . . ."[15] It was
this internist's interest in the thorax and
its topographical opportunities that resulted
in his employment of the *open* screen; per-
haps the first consistent use of this imple-
ment in this country. His predilection for
the open screen was due also to his practice
of making tracings, on glass, celluloid or
the patient's skin, of his observations cover-
ing the entire thorax. For this at least one
free hand was needed, and often two, for

we must remember that foot-control of current-supply was unknown at that day, diaphragm control was not to be exercised easily or quickly, and the behavior of the tube was governed by manipulation of bipolar series spark-gaps controlled by rods. The infant focus-tube was usually obstreperous, and to "spare the rod" was to "spoil the child."

Williams' devotion to the fluoroscopic use of roentgen rays naturally broadened his viewpoint as an internist to a degree quite beyond his time, because he perceived how the diagnostic powers of even the most skilful clinician might be amplified and refined thereby. "It has been said," he quoted in 1901 with thorough acquiescence, "that the 'x-rays are a most effective method of showing how great a rôle the imagination may play when using auscultation and percussion.'" By 1898, hardly over two years from Röntgen's discovery and through the medium of the fluoroscopic screen, Williams had discussed the application of the x-rays to the diagnosis of thoracic aneurysm, pericardial effusion, cardiac hypertrophy, cardiac transposition, emphysema, pleurisy with large or slight effusion, pneumothorax, hydropneumothorax and pulmonary tuberculosis.

Williams, of course, shared the common experience of the pioneer, whatever the undertaking. His belief and confidence in the revelations of the fluoroscope courted skepticism and even antagonism among his clinical colleagues. One of his publications on the subject was rewarded by this editorial appendage to a review of it:[16] "The author is evidently an enthusiast. It is unfortunate that he has confined himself so largely to work with the fluoroscope. Observations made in this manner are liable to errors of personal interpretation. . . ." As if, forsooth, the findings derived from other clinical methods, not excepting radiographic methods, were not, on frequent occasion, disposed to the same weakness!

One cannot contemplate the development of roentgenoscopy without recurring to the contributions of that ingenious

dental practitioner, William Rollins, whose name should have adorned the honorary roll of every radiologic society in the land. How many of us today are aware that he devised and used practically an intra-oral fluoroscope for the teeth, manipulated in the manner of the mouth-mirror? But it was as the faithful co-worker and mechanical genius of Francis Williams that he produced the extraordinary instrument he called the "seehear"—a fluorescent screen and a phonendoscopic diaphragm of equal size mounted in such relation to each other that the eye and ear of the examiner could appreciate conjointly the sights and sounds of the intrathoracic functions, or pathological departures from them.

Crane, of Kalamazoo, was another advocate of fluoroscopy in thoracic diagnosis whose contemporaneous enthusiasm was almost the equal of that of Williams. This was shown in a communication made by him as early as 1899,[7] in the course of which he describes his "skiameter," which, as its name implies, was a manual instrument for the mensuration of shadow-densities by means of a gauging scale, at first of metallic wires of varying cross-section and later of layers of tin-foil arranged in divers thicknesses. The depth of the given shadow beneath the screen surface could in this manner be determined from its intensity by an ingenious, if somewhat complex, application of mathematics. Crane's confidence in fluoroscopy was revealed by this sentence: "I trust that in this paper may be shown the superiority of the fluoroscope over the dry plate [the radiograph] in the examination of the lungs."

Williams and Crane, of course, were but two of a widely disseminated body of investigators that was moulding the advantages of scrutinizing inspection to the needs of thoracic diagnosis by means of the roentgenoscope, as it was now to be called, for, since the advent of the open screen, the term "fluoroscope," in the Edisonian sense, was no longer a comprehensive one. In this connection we should recall the names of Grunmach, Kienbock, Walsham, Holzknecht, Stubbert, Moritz, Levy-Dorn, and

Groedel, as well as that of Baetjer and certain of his American colleagues of a slightly later day. It is safe to say that some of these, by their support of thoracic fluoroscopy in terms of reason and conservatism, retarded the decline of the use of the roentgenoscope, while others, of more ardent enthusiasm, accelerated it—for a decline there was during the very early years of the present century. This reaction was the result of at least two influences, one of which was the increasing realization, especially among practical users of roentgen rays, that the fluorescent screen could be the source of very real danger to the operator. The first death from the effect of x-radiation in the United States, that of young Clarence Dally, an artisan of Mr. Edison at his West Orange laboratory, was recorded in 1904, and as late as 1905, Pfahler,[12] in a paper on the roentgen diagnosis of diseases of the lungs, admits his practical discontinuance of the use of the fluoroscope in the chest "because of its inaccuracy and of the dangers attending its use." Another influence making for such sentiment adverse to the practice of fluoroscopy was the steady improvement in radiographic methods, as shown by the creation of generating apparatus of more potent output and the development of intensifying screens of better quality; that is to say, of less granularity and phosphorescence.

But Research, in the meantime, remained true to her renown for courageous and persistent endeavor in the face of obstacles. Her devotees, so definitely aided by fluoroscopic methods in their investigations of the thorax and its contents, were not to be deterred by its anatomic boundaries. Below the diaphragm, as well, there was visceral motion to be scrutinized. There the organic structures were not endowed with sufficient natural contrasts of light and shade to make them visible; obviously, they must be made visible by artificial means, and, since the intra-abdominal portion of the alimentary tract, at least, was a structure in which motility was a very important phase of its physiology, it must be observed with the screen even as, in the thorax, the organs of respiration and blood-circulation had been observed.

It is of record that the earliest attempt to render visible by artificial means the course of the esophagus and the contour of the stomach was made by Strauss,[14] of Berlin, who, in 1896, used for this purpose gelatine capsules charged with reduced iron oxid and bismuth subnitrate. The shadows of these capsules upon his fluoroscopic screen were most indefinite and Strauss was evidently soon discouraged. He relinquished his investigations because, as he writes, "they appear to me to be of less practical importance than the question of changes in translucency of pathologic new-growth to the roentgen rays." The promptly subsequent work of Walsh, Hemmeter, Naegele, Benedict, Williams, Lester Leonard, Cannon, and others, employing products of the mineral kingdom *not* administered with food, is well known, but even more familiar to us are the famous investigations of Cannon on the digestive functions of the cat, whereby alimentary roentgen diagnosis was christened in a bread-and-milk suspension of the subnitrate of bismuth, the ritual of the ceremony being interpreted through the eminently proper medium of the fluorescent screen.

Many of us did not then realize, perhaps, the significance of Cannon's work and the manner of its doing. Many, through the following years of the first fluoroscopic depression, as one might call it, were timorous of the threatened physical danger in routine fluoroscopic procedure. On the other hand, many were smitten, almost overcome, by the charm of the rapidly developing attractions of radiography, that fascinating but occasionally disappointing damsel our Bavarian colleague, Rieder, in 1904, had taught us to woo. Up to the day of Rieder's epochal accomplishment with reference to alimentary topography and physiology, efforts at *depicting* the contours of these viscera were largely confined to tracings and to punctate outlinings, both of them fluoroscopic methods. Rieder's results

served as immense stimulation to others—most widely, perhaps, in Europe, but also here as shown in the early work of Hulst in 1905, Pancoast (with others) in 1906, and Pfahler in 1907. In short, American ski-agraphy of the alimentary tract was merely keeping pace with the steadily increasing excellence of our general roentgenography. Although the technical quality of the radiography of the European school was of notable merit, by 1910 we were abreast of it, thanks to the high standard set by Cald-well and other advocates of fastidious technic, and, within a short time, ahead of it.

Undoubtedly, this radiographic de-velopment of ours had continued for some years at the expense of our roentgenos-copy. It was probably an excellent thing for both the European and American schools of radiologic practice that we were visited in 1910 by Haenisch of Hamburg, then the associate of Professor Albers-Schoenberg, as an official delegate to our national society meeting. After the meet-ing he visited many of our individual laboratories. Writing, later, in the Ger-man *Fortschritte* of his impressions, he said, in part: "We were surprised to find how little use is made of roentgenoscopy. The unfortunate accidents which followed the excessive use of the fluoroscope in the early days of roentgenology have brought radioscopy into disrepute [in America] and only of late is this method beginning to be introduced by certain practitioners who have travelled in Europe and are convinced that for certain cases screen examination is absolutely essential. . . ."

"Certain practitioners," thus referred to, made up a group of which Pfahler, Wil-liams, Hulst, Skinner, and others were ardent members, and as a whole the report of Haenisch described with reasonable ac-curacy the setting of the American radio-logic stage at the moment of the entrance upon the scene of one who, by force of his example and the conviction created by his writings, aided mightily in putting to an end the first American fluoroscopic de-pression—Russell Carman.

The course of Carman's professional life as a roentgenologist may, as we know, be divided into his shorter Saint Louis period and his thirteen fruitful years at Rochester, where he labored so diligently and so effectively. At the beginning of 1913, the resources in material he found at the Mayo Clinic served immediately to stimu-late his predilection for gastrointestinal in-vestigation and the practice of roentgen-oscopy it involved, of which the results of his work in Saint Louis had already given indication. He found at Rochester the sympathetic yet reasonably critical attitude of one's colleagues that means so much to the pioneer in any form of specialized endeavor, and which stimulates his coöperative activity to the same degree that colorless assenting agreement retards it. The practice of roentgenoscopy is es-sentially a matter of close relationship be-tween practitioner and patient, permitting of no delegation to subordinate hands. Therein lies its purity as a true Æscu-lapian ministration. Thus, at Rochester, it was Carman's happy lot to remain what he had set out to be—a physician rather than a scientist of the laboratory; for, however we may misapply in the name of convenience, the noun "laboratory" in speaking of the seat of radiologic practice, or, for the same reason, carelessly use the term "clinician" in contradistinction to the status of the radiologist, the fact remains that radiology is and ever will be a clinical branch of the practice of Medicine.

It were impossible to amplify the true words already spoken, under this Lecture-ship, by Doctor Moore concerning the ac-complishments of his preceptor, and the way in which they should influence the con-duct of him who would undertake to solve the problems of roentgenology in ab-dominal diagnosis, but no consideration of the growth of American fluoroscopy could even approach completeness without a brief review of Carman's profound and salutary influence on it.

There is ample evidence in his writings to show that from the first moment of his radiologic activity he held the early in-

vestigations of Cannon in high appreciation. The fact that this work was based on the observation of visceral motion appealed to his sense of the importance of elucidating the presence of alimentary disease through the scrutiny of departures from the normal physiology. Thus he was moved to deplore the evident lack of early American interest in the future outcome of Cannon's contribution. It was over twenty-two years ago, as we were recovering from our first fluoroscopic depression, that Carman wrote:[11]

"It is to be regretted that a method which gives promise of such an advance in methods of gastrointestinal diagnosis, and which owes its inception to an American, Cannon of Boston, should have awakened in this country as yet so little interest as compared to that evinced by German and English clinicians and roentgenologists."

Carman's genius for roentgenoscopy was almost intuitive. Well before 1913, when one may say his broad contact with alimentary disease began, it had made itself evident. It was in 1910—the year, in fact, of Haenisch's report on the meager use of fluoroscopy in the United States—that Carman thus expressed himself, in dealing with the subject of medical roentgenology as a specialty:[1]

"Roentgenoscopy deserves separate and praiseworthy mention. By the use of the fluoroscope and its modifications, the diagraphoscope and the orthodiagraph, physiologic and pathologic processes may be observed and studied *intra vitam*. Many of the phenomena of the circulation, of respiration, of digestion, can be seen in action. The progress of a peristaltic wave in the stomach, the pulsation of an aneurysm, the splashing of a pleural effusion, can all be viewed directly. *These must be seen on the screen, and not on the plate, to be of any direct value in diagnosis.*"

And again, the following year:[2]

". . . it is not extreme to say that no x-ray examination of the chest or abdomen is complete without the use of the fluoroscope, and it should precede skiagraphy. . . . Upon the screen, living dynamic pathology is seen. On the other hand, the plate is a record of a single phase of conditions, which may be 'accidental or improvised,' as Holzknecht says."

These trenchant statements, made twenty-five years ago, may well be interpreted as Carman's confession of faith in the value of a procedure that had impressed him deeply from the early days of his medical career and which he applied consistently during the remainder of his life. As the immediate result of this application was formed the first expression of what may be termed the Carmanian influence on the present status of American roentgenoscopy. It is conveyed by these words:[2]

"Emphasis must be laid upon the necessity of observers remaining in the dark for at least twenty minutes before beginning the examination. The eyes then become accustomed and details, which otherwise would be lost, are plainly seen."

This point, small as it seems to be now that a world-wide fluoroscopic routine is established, was then of the greatest importance, and one which Carman iterated frequently; so, in later years, when it became generally known that this pupillary preparation was a part of the Mayo practice, and, since suggestions *ex cathedra* usually carry more weight, one's clinical colleagues elsewhere, perhaps acutely concerned in a given fluoroscopic problem, became less impatient of what had seemed to them a silly and unnecessary delay, and less expectant of a brilliantly detailed screen image the instant they entered the realm of roentgenoscopy from the bright light outside it.

At the outset of his day's screening, Carman had a most palatable remedy for impatience of this sort. Who of us oldsters does not remember those preliminary moments of general conversation in the darkness of the screening-room at Rochester, as we waited for our pupils to dilate—pupils ourselves, for the moment, of a great fluoroscopist, and in the very pleasant meantime dilating freely on every conversational subject, *except* radiology, from motor cars down?

There can be no doubt of the weight of Carman's diagnostic work, especially his gastrointestinal roentgenoscopy, as affecting the readjustment of our statistics rela-

tive to the incidence of duodenal ulcer. In 1914, in one of his many discussions on the subject, he took occasion to raise a collateral point which has subsequently done much to establish closer *liaison* between hospital roentgen departments and other clinical services, surgery in particular. Said he:[4]

"Notwithstanding the constantly growing mass of convincing statistics, many clinicians and especially a few gastroenterologists of this country and continental Europe are on record as claiming that duodenal ulcer is a lesion which rarely occurs. Their inability to recognize its frequency is probably due, as W. J. Mayo states, to the presence of the abdominal wall. Speaking from a radiologic point of view, I might say that during the last year only have I come to realize the frequency of this condition through following cases to operation and looking into the abdominal cavity with the surgeon. I would certainly recommend this procedure to those that are skeptical, because a large number of the patients treated for 'chronic dyspepsia' have duodenal ulcer. . . ."

That "year" to which Carman refers—his "year of realization," as it were—was his first year at Rochester. It is probable that, even at that early day, he carried with him to the operating room well-thought-out diagnostic information which, more often than seldom, it was merely for surgery to corroborate. But what soon became apparent was the *spirit* in which he invariably approached the test of surgical revelation. Counterevidence or disproof, when it was forthcoming, he accepted in the acquiescence of the true scientist, nay, he welcomed it with the warm partisanship of the humanitarian if the findings redounded to the advantage of the patient. Carman early formed this habit of operating room attendance, and its obvious advantages to both surgeon and roentgenologist soon became generally recognized. Its constructive effect on the hospital roentgenologic units of the country was the creation of a spirit of thorough interdepartmental understanding and coordination through opportunity for truly clinical comparison of evidence. Who shall say that this spirit, now so generally manifested everywhere, is not another expression of the Carmanian influence on the status of American roentgenoscopy?

From Carman's habit of establishing and fostering such close clinical association with his colleagues, results of combined observation of the greatest worth were the inevitable outcome. Attesting to this is the exceedingly important communication of Carman and Balfour,[6] in 1915, in the matter of gastrojejunal ulcer. Up to that moment, consideration of this lesion had been preponderantly surgical, and roentgen-ray evidence in diagnosis, when utilized, had been inconclusive. Doctor Moore, from this rostrum last year, mentioned the far-reaching results of this report; for our consideration today be it said that the 14 cases by way of illustration were accurately and in detail described on a basis of initial fluoroscopy. "Roentgenoscopy," writes Carman in this paper, "is particularly necessary in examinations for gastrojejunal ulcer," and proceeds, by the conclusions of the authors, to prove the truth of a statement that has since become an axiom. From the purely historical viewpoint this paper is equally important, for Carman's share in it gave him the opportunity to pour oil on the waters of controversy that were already becoming turbulent. His words reveal the nature of the discord:

". . . In every examination of the digestive tract both roentgenoscopy and roentgenography should be employed. They should not be regarded as independent competitive methods, but as complementary parts of one method, for exclusive reliance upon either alone is likely to result in overlooking some important feature of a case. . . ."

Carman had no taste for petty polemics. "Controversies, sometimes heated, but Pickwickian," as he once wittily classified them, were against his very nature, but in maintaining the larger defences of his position he was strong. It was this strength, added to the prominence of his station in American Medicine, that made his the protagonistic key-position in what has been loosely termed the "fluoroscopic school of thought" in roentgen diagnosis in this country, especially as applied to the digestive tract at the moment of which we are now speaking. This school of thought,

or, more properly, of practice, "was an evolutionary product of the so-called Continental doctrine, in that its mode of investigation was basically roentgenoscopic, formulating its diagnosis, after the precepts of Holzknecht, on a factorial consideration of the 'symptom-complex' presenting in the given problem, as well as upon its radiographic records in confirmation." These principles had their advocates in men of such strength as Forssell, Haenisch, and Barclay and, in this country, among others, Crane, Hulst, Pfahler, Case, and Skinner.

Carman's breadth of mind embraced all phases of his work and permitted of no bigotry as to the infallibility of his theory and practice. His readiness to admit the possibility of their points of weakness or doubt seemed to amount almost to an obsession. He wrote entire papers on the limitations of roentgen diagnosis, but in the furtherance of any tenet that he had proven to be sound, he was as firm as bedrock. The fact that the findings of roentgenoscopy played so important a part in the procurement of the data that gave to the work of Carman and Balfour its great value, together with the fact that this work showed conclusively that accurate and detailed circumstomal roentgen diagnosis may spell the difference between postoperative comfort and postoperative misery that "maketh the heart sick," would seem to indicate, it is believed, that herein lies yet another expression of the salutary Carmanian influence on the development of fluoroscopy.

By his display of common sense, Carman had done much, as has been said, to allay the growing fear of fluoroscopy which he found to exist when he entered the practice of radiology, and somewhat later, during the first year of his Rochester period, or, to be more exact, twenty-two years ago, in this city, in this month of June, by means of a paper describing his technical methods,[3] he gave voice to his views on the fluoroscopic depression brought about by an hysterical timidity that had taken the place of sensible caution. To those about

to discard their fluoroscopic apparatus he suggested the exercise of temperance rather than prohibition. "I would not urge any roentgenologist," he said, "to take risks which to him seem imprudent and which might possibly result in his injury, but candor compels me to express my very sincere belief that we have gone from one extreme to the other, from extraordinary and ignorant rashness to extraordinary and unnecessary caution." He deplored the influence of this unnecessary caution as was shown in the heavy and unwieldy construction of much of the fluoroscopic apparatus of that day. Since this ponderous construction prevented effective access to the patient for purposes of palpation, Carman reasonably complained that "the screen examination, thus 'denatured,' loses half its interest and value." Those who were screening before Carman's day, or even contemporaneously with his earliest gastrointestinal practice, will be prepared to agree that this protest of his against such Gargantuan architecture in screening apparatus whereby, amid its pillars and flying buttresses, the person of the unprotesting patient became effectually shielded from all efforts of the palpating hand, was the beginning of a reactionary period of simplicity in the construction of these devices—another manifestation of the "Carmanian influence," but perhaps of lesser importance than many others, in spite of its specific value.

But this reaction in the direction of increased simplicity, while it had its permanent good effect on after years, became much too pronounced under the stress of the urgencies of the Great War. Roentgenoscopic practice constituted almost ninety per cent of the military radiologic activity in intermediate areas behind the dressing station zone and as far back as the base hospital. By the very simplicity of its construction, much of the apparatus in such areas was woefully inadequate as far as protection of the operator was concerned. At casualty clearing stations or evacuation hospitals, screening apparatus was necessarily of simple installation with

a view to its quick removal in case of forced retirement.

Not many months after the close of the War, possible results of over-exposure to x-rays in the Service and otherwise were being noted in the occurrence of aplastic anemia and other blood dyscrasias. Perhaps because of the subtlety of these effects, perhaps by reason of wider publicity, greater agitation was created than had been the case fifteen years before. The second fluoroscopic depression was on; many relinquished completely the use of the screen, and roentgenoscopy seemed about to receive another periocular contusion, as it were. Russell Carman, however, from the stronghold of his now eminent position, treated its prodromal signs, as he had done previously, with the cold compress of common sense. His temperate attitude was matched by that of others of his peers who realized that any curtailment of the growing beneficence of roentgenoscopy was unthinkable, and that radiation-danger, not only to its devotees but in any form of radiologic practice, could be controlled only by concerted regulation of the element of protection, and not by haphazard effort. Accordingly, in 1920, the American Roentgen Ray Society formed its standing committee for roentgen-ray and radium protection. The movement was soon taken up by similar societies in Great Britain, and there had the strong and influential support of the National Physical Laboratory to a degree not as promptly reached by our National Bureau of Standards. The subsequent development of this activity is familiar to all; through Continental coöperation there has been created the International Committee on X-Ray and Radium Protection, and among us there has appeared the Bureau of Standards Handbook on Roentgen-Ray Protection.

In spite of these organized precautionary measures, to which the registered American radiologist must subscribe and comply, and thus may practise his profession with absolute safety to his patient and relative safety to himself, the untoward

potentialities of uncontrolled fluoroscopic practice are still with us. There yet endures the unprincipled charlatan who, within the mystifying aura of the roentgenoscope, seeks to hoodwink his trusting victim as he shamelessly lies into credulous ears as to what the luminous screen reveals. We still have the manufacturer who is so far unmindful of the respect of the qualified radiologist that he continues to persuade the internist or the general practitioner of the advantage in the possession of a fluoroscope as a bit of decorative office furniture, which it is ultimately to become after producing its yield of disappointment. Also, there is the less serious matter of the commercially wolfish shoe dealer garbed in the sheep's clothing of science, as he asks us to enjoy, with him, by fluoroscope, the sublime vision of our *hallux valgus* which he proposes to fit, plus or minus, into the tight leather of vanity. Roentgenoscopy, with all our modern devices for protection of the operator, is still, in unpractised hands, a procedure potentially serious, to use no stronger an adjective. So is any manipulative undertaking wherein are combined the "personal equation" and a complex distribution of high-voltage electricity with the radiation phenomena attending it. The laws of physics may be impeccable, but human agencies are defective. Hence the value and applicability of the fluoroscopic observations of Barclay, of the University of Cambridge, or the more recent researches of the Americans Cilley, Leddy, and Kirklin.

During the later years of Carman's life, two events occurred which must have been to him exceptional sources of satisfaction. One of them was the amplification by Forssell and Akerlund of Forssell's early work of 1912 on relief-demonstration of the alimentary mucosal folds. In this later elaboration, Carman could see developed one of the first manipulative adjuncts to fluoroscopy which he had practised and taught—screen observation under applied pressure; not mechanical pressure by cones or cylinders or balloons that since may have added to the accuracy of these

observations, but pressure of his good right arm, with a "palpatory eye" at the tip of each finger! Carman's physique afforded him aid that no man of lesser build could hope for.

The other satisfaction must have been the fruition of the work which Moore authoritatively declares to be the great contribution of Carman's life—the discovery of the "meniscus sign" of ulcerating gastric cancer. With what pride Carman states in his report[5] that fluoroscopy is essential for the demonstration of this lesion, because manipulation is nearly always requisite for its exhibition—such was his fascination by the rewards of palpatory effort!

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The Roentgen Diagnosis of
Vitamin-Deficiency Cardiac Conditions

With Some Clinical Observations on Thiamin Deficiency[1]

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IT HAS BEEN established that certain types of vitamin deficiency are of not infrequent occurrence in this country (5, 18, 24, 25), although serious deficiency is probably neither as frequent nor as severe as some vitamin enthusiasts and many faddists would have us believe (3). It has been observed that certain types of vitamin deficiency are frequently associated with cardiac enlargement (18, 22, 23). Having seen the cardiac roentgenograms of several patients with one type of avitaminosis, it was decided to review these and to investigate certain other types, both clinically and through the literature, with the aim of ascertaining the existence of roentgen diagnostic criteria, if any.

AVITAMINOSIS

The term avitaminosis has been applied to variable degrees of vitamin deficiency, ranging from mild and questionable to advanced, terminal stages (16, 24). The expression "vitamin deficiency" is probably preferable, since it does not connote total absence of vitamins, as does the first term. For several years following recognition of the fact that a lack of certain vitamins might cause disease, it was customary to regard each disorder as a specific etiological and clinical entity, although naturally with a variable symptomatology. Hess and others emphasized that experienced physicians found difficulty in differentiating some cases of adult scurvy from beriberi, and stated that the term "ship beriberi" implied a combination of these two diseases (5). Recent observations on

the effect of deprivation of a single vitamin in normal subjects, maintained on carefully controlled diets, have shown that it is often difficult to produce the symptoms of a single deficiency by such means alone (19).

It has been found that in clinical practice few patients present all the signs attributable to any single avitaminosis, and that many cases when examined carefully show the signs of two or more types of vitamin deficiency (19). Certain "patterns" are more common than others, chiefly those of the B group deficiency. Classic pellagra frequently presents the cheilosis and corneal vascularization of riboflavin deficiency, and the muscle tenderness and reflex disturbances of thiamin deficiency. Patients with beriberi often show not only neuritis and cardiovascular disturbances, but also glossitis and dermatitis characteristic of riboflavin and nicotinic acid deficiency. Scurvy and rickets may coexist in children. In other words, clinically the picture is apt to be one of multiple vitamin deficiency rather than of deficiency of a single vitamin, and B, being shall we say the dominant vitamin, tends to be the conspicuous one in the clinical syndrome.

Vitamin deficiencies are probably of only occasional clinical importance in everyday practice in this country, except in impoverished sharecropper and slum communities (and in a few Negro and Indian sectors), but experience after the last war indicates that they may be of more than academic interest to many of us in the near future. Several cases of adult scurvy occurred in the troops engaged in Mesopotamia in 1915 and 1916; the civilian populations of certain large European cities were afflicted with the disease,

and numerous cases of infantile scurvy were associated with it (5). Along with such "epidemics" of vitamin-deficiency states, there may often be an associated general nutritional deficiency, notably of proteins.

Vitamin deficiencies, as seen in ordinary practice, occur for various reasons: inadequate intake (faddism, alcoholism, special diets, errors in cooking), inadequate absorption (gastro-intestinal tract disorders), and increased need (pregnancy, lactation, febrile disorders) (25).

In this respect the conditions predisposing to thiamin deficiency differ somewhat from those which encourage deficiency of the other vitamins and indeed of the other "B" fractions. Under circumstances which engender general under-nutrition, other deficiency states than those due to lack of thiamin are far more prone to occur; and dependence on preserved foods, if enforced over long periods, is more likely to culminate in scurvy than in beriberi. On the other hand, in civilized communities in which a reasonable standard of living is the general rule, evidences of thiamin deficiency are far the most common. This interesting trend is the product of the metabolic facts:

1. Thiamin is probably the most poorly stored of all the vitamins, leaving a smaller reserve margin for periods of deprivation.

2. The metabolic requirement for thiamin is directly proportional to the caloric intake, excepting that furnished by fat. The consequence of the latter metabolic factor is to make it entirely possible for a well nourished individual of adequate economic status to develop beriberi, and to render its appearance unlikely in those who are undernourished. However unwelcome the fact, it is incontrovertibly true that, while as a nation we enjoy the highest standard of living ever known, our thiamin intake is marginal. Though thiamin is extraordinarily ubiquitous in its natural distribution, there are few foods which contain more than a sufficient quantity of this substance to guarantee their own orderly metabolic breakdown in the body, whereas most of the artificial foods contain none at all, and it is the latter which require the greatest quantity of thiamin for proper utilization. There is no worse offender in this respect than alcohol, which furnishes approximately 8 calories per gram and supplies no thiamin whatever. This is reflected in the frequency with which alcoholism is a forerunner of beriberi, neuritis, and heart disease.

One of the more marked cases of cardiac enlargement to be illustrated below occurred in a lady who chose to put herself on a diet of pure honey and nothing else for three months! Experience has shown that in groups of people deprived of all known vitamins for long periods of time different types of deficiency manifestations appear. Some may show no clinical evidence of vitamin deficiency at all, presumably owing to unusually large body storage plus small body needs. Restricted carbohydrate intake delays or prevents the appearance of symptoms of vitamin B deficiency. It is believed that natural foods (that is, ordinary amounts of fresh vegetables, meats, carbohydrates, and fats) provide a harmonious and adequate combination of vitamins, and that artificial administration of vitamins should be resorted to only for clinically definite deficiency states.

VITAMINS

A few years ago vitamins were conveniently known by a few alphabetical letters, giving them a pleasantly simple connotation. Now unfortunately they have acquired complex chemical names, difficult for clinician and radiologist alike to remember. Further, certain of the vitamins, notably vitamin B, have been subdivided into a bewildering number of subgroups, many of which have been synthesized. The following list is for the convenience of those who wish to have a tabloid version of our *present* conception of these substances, their sources, and the conditions produced by their deficiency:

Vitamin A, or carotene, is found in various fish-liver oils, green and yellow vege-

TABLE I: PRINCIPAL FINDINGS IN VITAMIN DEFICIENCY

Vitamin and "Synonym"		Clinical Findings	X-Ray and Laboratory Findings
A	Carotene	Nyctalopia; xerophthalmia; epithelial keratosis	Decreased blood A. Adaptometer tests (?)
B	B_1 Thiamin	Peripheral neuritis; muscle tenderness; *cardiovascular disorders;* gastro-intestinal disturbances; fatigue (beriberi)	X-ray changes in *heart* and small bowel. Decreased urinary and blood B_1
	B_2 Riboflavin (G)	Glossitis; photophobia; labial corner fissures	Vascularization of cornea (slit lamp study)
	Nicotinamide Nicotinic acid	Glossitis; diarrhea; red, scaling dermatitis on dorsum of hands; fatigue (pellagra)	Decreased urinary and blood nicotinic acid
	B_6 Pyridoxine	Nervousness; irritability; weakness	Decreased urinary B_6
	Biotin Inositol Pantothenic acid Folic acid	Unknown	None
C	Cevitamic acid	Spongy bleeding gums; bone and joint pain; bleeding (scurvy)	X-ray bone changes (infants); low plasma C (below 0.75 mg. per cent)
D	Irradiated ergosterol	Muscle weakness; disturbed Ca and P metabolism; infantile tetany (rickets)	X-ray bone changes (children); low blood P; phosphatase increase ?
E	Alphatocopherol	Unknown. Sterility in rats	None
K	"Methylnaphthoquinone"	Bleeding in newborn and in hepatic diseases	Increased clotting time (prothrombin deficiency)

tables, eggs, milk, butter, apricots, oranges, and bananas. Its deficiency results in epithelial tissue disorders—night blindness or nyctalopia, xerosis of the cornea, and keratosis of the skin.

Vitamin B, or B complex, occurs in yeast, wheat germ, and the organs and muscles of many animals, especially liver. Deficiency is associated with peripheral neuritis, cardiac enlargement, glossitis, dermatitis, and various gastro-intestinal and nervous system disturbances. The B complex includes the following subdivisions: vitamin B_1 or thiamin, B_2 or riboflavin, nicotinic acid, biotin, and other vitamins the significance of which in human nutrition has not yet been clearly established. These others include B_6 or pyridoxine, inositol, pantothenic acid, and folic acid.

Vitamin C, also known as cevitamic acid or ascorbic acid, is found in citrus fruit, tomatoes, and green vegetables. Deficiency results in scurvy, both clinical and latent.

Vitamin D is present in various fish-liver oils, eggs, butter, and milk. It is the only vitamin which the body is known to synthesize. Deficiency results in rickets (infantile rickets), disturbed dentition, and disturbed calcium and phosphorus metabolism.

Vitamin E, of which alphatocopherol is one synthetic fraction, is found in green leaves and wheat germ. Its significance in human nutrition is not known; it appears to be necessary for normal pregnancy and normal growth in rats.

Vitamin K, a complex methylnaphthoquinone, occurs in certain vegetables such as spinach and tomatoes. Deficiency results in prolonged clotting time, lack of prothrombin, and certain hemorrhagic disturbances.

CARDIAC DISORDERS

The roentgen diagnosis of cardiac disorders depends on the detection of changes in the size, shape, position, and movement of the heart. Of these signs, alteration in size is one of the most important (at least in non-valvular disorders). The determination of true increase in cardiac size is not always simple, especially in per-

sons of unusual build. The probability of enlargement, however, can usually be predicted fairly reliably from roentgen examination, and can be confirmed in certain vitamin-deficiency disorders by change in size after a short course of appropriate vitamin therapy.

The most satisfactory single index of probable cardiac enlargement (although far from the most reliable) is the total transverse cardiac diameter as measured on a 6-foot posterior-anterior roentgenogram of the chest made in moderate inspiration (6, 12). If this diameter is less than half the internal hemithoracic diameter as measured at the level of the left diaphragm, the probability is that the heart is not enlarged. Conversely, if the diameter greatly exceeds half the internal hemithoracic diameter, the probability is that enlargement is present. In hyposthenic or lanky individuals this measurement is quite unreliable, since such persons normally have very slender hearts and significant enlargement may be present but not detectable radiologically from a single examination; conversely, in hypersthenic or stocky individuals a perfectly normal heart may appear to be enlarged both radiologically and clinically. If allowance is made for variation in body types, intelligent roentgen conclusions can be drawn. Marked deformities of the bony thorax, depressions of the sternum, disturbances of the diaphragm, etc., must also be suitably discounted in making this particular cardiac measurement. Finally, accidental variations in intrathoracic pressure produced by unconscious "Valsalva conditions" may cause confusion in an occasional case (see Fig. 1). As previously mentioned, it is the *comparison* of the total transverse cardiac diameter, made under similar conditions of respiration from one examination to another, that determines the existence of enlargement in clinically proved cases, and this fact renders absolute decision on a single film of minor importance in equivocal cases.

Alterations in shape and movement of the heart usually accompany alterations in size in cases of severe vitamin-deficiency cardiovascular disease. The heart shows general enlargement until the terminal phase appears, at which time marked relative right heart enlargement frequently manifests itself. Movement (pulsation) is impaired and may diminish dramatically in severe thiamin deficiency. This impaired contractility is well seen *fluoroscopically* and may be neatly recorded by roentgenkymography, as shown in Figures 11 and 12 (8, 11). It is always associated with indirect signs of cardiac dysfunction in the form of passive congestion of the lungs, edema of the dependent portions of the body, and dyspnea on exertion. The pulmonary edema is usually masked at roentgen examination by the associated passive congestion.

Having established the existence of probable or definite cardiac enlargement and impaired contractility, how can vitamin deficiency be distinguished from the host of other possible causative factors? Chiefly by a prompt and striking response to specific vitamin therapy. If an enlarged heart shrinks about 3 cm. in its total transverse diameter in a period of ten days on suitable therapy (especially thiamin chloride), then the enlargement was almost surely due to vitamin deficiency. Total lack of response usually excludes avitaminosis, except in terminal, irreversible failure.

CARDIAC ENLARGEMENT IN CONDITIONS SOMETIMES ALLIED WITH VITAMIN DEFICIENCY

The marked and sometimes dramatically reversible cardiac enlargement seen in certain types of B deficiency is not paralleled by that of any other non-valvular condition except perhaps arteriovenous fistula and myxedema (14, 15, 20). Severe protein deficiency and anemic states, however, are sometimes associated with cardiac enlargement which is said to be reversible (2, 15). We have seen no case where the change was as marked as in a typical thiamin-deficiency heart. It is said that the protein deprivation or the anemia must be unusually severe and prolonged to result in
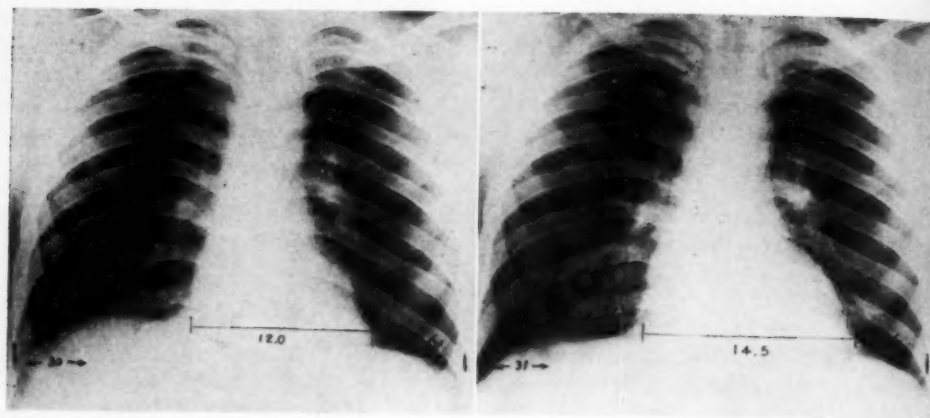
Fig. 1. Change in cardiac size produced by voluntary alteration in intrathoracic pressure. Healthy male, 28 years. Films made at 6 feet: on left, at end of quiet inspiration; on right, at end of quiet inspiration followed by attempted expiration against a closed glottis (for ten seconds). Note that diaphragm is at same level in both films (left 6th rib anteriorly), and that the transverse diameter of the heart diminishes 3 cm. under the Valsalva test. Such a condition occasionally occurs with nervous or uncomprehending patients, and must be guarded against in routine technical work.

cardiac enlargement. In simple starvation, cardiac size diminishes slowly.

The decompensated heart of mitral insufficiency may show prompt and remarkable diminution in size under appropriate therapy, but this lesion should not cause any problem in differential diagnosis.

We shall now consider the question of cardiac enlargement in specific types of vitamin deficiency in which it has been reported and will record our own observations on this problem.

CARDIAC ENLARGEMENT IN VITAMIN D DEFICIENCY

In severe cases of rickets variable degrees of cardiac enlargement have been reported, consisting chiefly of ventricular dilatation and hypertrophy (1, 5, 26). The roentgen diagnosis of such changes is difficult, since in infants the cardiac silhouette is normally relatively large in proportion to the size of the chest. We have been able to find no convincing roentgenogram showing regression of an enlarged cardiac silhouette following specific treatment, although one experienced physician reported observing such regression after large doses of vitamin D in a rachitic infant (5).

We examined the roentgenograms of 4

cases of infantile rickets and 5 cases of combined rickets and scurvy seen over a period of years at the San Francisco Hospital and could detect no instance of definite or reversible cardiac enlargement. The diagnosis of rickets was based on the usual clinical criteria plus unequivocal roentgen changes (namely flaring, irregularity, and concavity of the diaphyseal ends of the long bones and ribs, with some general demineralization and occasional multiple osseous bowing or fractures). Two of the rachitic infants had signs of severe vitamin deficiency and yet no convincing cardiac enlargement could be detected. While Abt (1) has reported cases of such enlargement, Weiss (22) believes that "at present one is justified in assuming that the cardiac changes observed in rickets may be attributed to the simultaneous presence of vitamin B_1 deficiency." Földes regards rickets as due to a combination of D deficiency plus endocrine and general nutritional disorders.

CARDIAC ENLARGEMENT IN CEVITAMIC ACID DEFICIENCY

There is a considerable literature on cardiac disturbances in scurvy, chiefly adult scurvy (5, 7, 20, 26). Most of the available roentgenograms, however, have
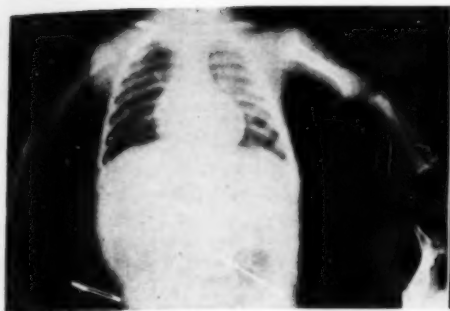
Fig. 2. Severe D deficiency. J. G., male, 8 months. Note marked rachitic flaring of ventral ends of ribs and long bones, with cupping and irregularity of the latter. Cardiovascular shadow normal in shape and size.

Fig. 3. Severe cevitamic acid (vitamin C) deficiency. C. L., female, 12 months. Note subperiosteal hemorrhages, and dense zones at the diaphyseal ends of the long bones. The cardiovascular shadow is normal.

been made on the chests of infants, and no sets of convincing films are available, on which a definite roentgen diagnosis could be made of cardiac enlargement with therapeutic regression. One well known pediatrician published some roentgenograms which he described as showing an enlarged heart in scurvy, but we believe that few radiologists would agree with his conclusions (5)!

We examined the films of one case of infantile scurvy and 5 cases of combined scurvy and rickets seen at the San Francisco Hospital and could detect no definite cardiac changes. The criteria for diagnosis included the usual clinical evidences of the disease plus the following roentgen findings: linear density alterations at the diaphyseal ends of the long bones, multiple subperiosteal hemorrhages, and occasional epiphyseal separations. Wolbach and others have described cardiac enlargement in scurvy, but Weiss again observes that concomitant unrecognized B_1 deficiency may be the causative factor.

In adults, the diagnosis of scurvy is now facilitated by noting the blood-plasma cevitamic-acid level—the normal being about 0.25 mg. per 100 c.c., the scorbutic from that level down to zero. We reviewed the roentgenograms of two clinically definite and severe cases of *adult* scurvy seen at the San Francisco Hospital; neither showed evidence of cardiac enlargement, and the clinical and electrocardiographic

findings were also negative for cardiac impairment.

There have been numerous reports of necropsies on infants with scurvy; some of these showed ventricular dilatation and hypertrophy, with moderate amounts of pericardial fluid (1, 5, 26). In adults, autopsies are reported showing fatty degeneration and hyperemia of the cardiac muscles, occasionally with hemorrhagic pericarditis (22, 26). We have been able to find no reproductions of roentgenograms of these particular cases.

CARDIAC ENLARGEMENT IN THIAMIN DEFICIENCY

Cardiac manifestations of B_1 deficiency are much less frequent in this country than neurological manifestations. The morbidity is none the less such as to preclude the attitude that beriberi heart disease is a rare condition. Vastly more important than its relative frequency are its grave and often fatal proclivities. It is set apart from almost all other heart diseases because it is preventable and usually curable in the true sense of that word. It can be the most swiftly destructive of all the deficiency states and yet yield the most gracefully after correct diagnosis has been made and specific therapy instituted.

Heart failure in beriberi does not present either a rigid or a specific clinical picture, and the diagnosis cannot be made by physical examination alone. There are,

however, certain clinical aspects which are conspicuous and which in the aggregate are suggestive of this disease. Distinguishing it from the more commonly encountered causes of heart failure one may list:

1. The edema is usually extreme, is disproportionate to, and frequently appears before, dyspnea. It has a marked tendency to involve the genital regions. It is probably augmented by other factors than heart failure, such as lowered serum protein.

2. A gallop rhythm is common.

3. Hypersensitivity of the carotid sinus is common, with a tendency to sudden and serious vasomotor collapse, resulting not infrequently in unexpected demise.

4. Despite a high level of the venous pool, the circulation time remains normal or accelerated; the clinical counterpart is warm extremities.

5. The pulse pressure is commonly, though not invariably, wide, becoming narrowed by a *rise* in diastolic pressure as the edema fluid is mobilized during the recovery stage.

6. Some degree of peripheral neuritis is consistently present.

7. Serum protein values are lowered.

8. The association of other deficiencies, more particularly of the other "B" fractions, is seen.

9. The type of response to therapy is dramatic and occurs in no other form of heart failure.

Judging from the early literature on the roentgen appearance of the heart in beriberi, and the description of the heart as seen postmortem, one might expect that the majority of cases would show marked right heart enlargement, with dilatation of the superior vena cava (23). In our experience this has been exceptional. The roentgen appearance is that of generalized cardiac enlargement with moderate passive congestion of the lungs, and we suspect that there is no characteristic roentgen diagnostic feature. Serial examination, with a rapid decrease in the size of the heart after specific therapy, permits a roentgen conclusion as to the existence of

the lesion, but roentgen diagnosis can rarely be made by a single examination.

A small percentage of patients are said to suffer the symptoms of beriberi heart without roentgen evidence of cardiac enlargement. Since it is often impossible (with available clinical and laboratory tests) to show that such patients have true thiamin deficiency, the existence of the lesion is difficult to prove.

The chief postmortem finding in patients dying with thiamin deficiency is usually slight enlargement of the heart, with moderate dilatation of the right ventricle. It has been observed by Weiss and others (22, 26) that dilatation of the right ventricle is not so marked in cases occurring in this country as it apparently was in those studied by Aalsmeer and Wenckebach in Java. The histologic changes consist of hydropic swelling of the myocardial fibers, swelling of the collagen, and perivascular edema. Of these, our pathologists (Drs. A. C. Cox and D. A. Wood) regard only hydropic swelling of the muscle ("vacuolated fibers") as being characteristic.

It has been suggested that the marked reversibility seen clinically is due to combination of this myocardial "edema" with widening of the smaller arterioles in the general circulation—sometimes described as a sort of diffuse arteriovenous fistula (15, 23).

The response of the heart to specific treatment is as variable as the manifestations of the cardiac disturbance itself. In general, it appears that improvement is most rapid in those cases showing a severe degree of congestive failure of relatively short duration. Such cases may show striking clinical improvement in a few days with astonishing diminution in heart size. That this response is characteristic of B_1 deficiency is shown in patients first kept in bed on a regular diet but not given thiamin. Such patients show no significant change in a period of ten days, whereas they respond dramatically to large amounts of thiamin within two days. It is also noteworthy that the improvement in the car-

diac symptoms is usually more rapid and more striking than improvement in the neurological disturbances, at least as far as neuritis is concerned; sometimes certain associated psychotic disturbances improve rapidly.

Descriptions of the roentgenologic appearance of the heart in moderately and well advanced cases of beriberi are quite varied (15, 23). One well known author states that the heart is characterized by a globular enlargement with a marked bulge on the right lower border, and a dilatation and displacement of the pulmonic arch (15). We have not seen this in any case. Another states that the enlargement becomes extreme and is of the mitral type (9). It is granted that at autopsy the enlargement of the right half may be striking, as may be dilatation and apparent displacement of the pulmonary conus; however, such is not the common manifestation *in vivo*. In the terminal stages of fatal cases, we have seen right heart enlargement become relatively marked, but without associated conus enlargement.

Beriberi has been reported in children and infants, and authentic cases of cardiovascular enlargement are on record (1, 5, 21). In this country it has been said that certain B-group deficiencies in childhood are usually associated with general dietary deficiency, and that the cardiac changes are perhaps not due exclusively to the B deficiency. Waring (21) has reported a group of 13 cases of "nutritional heart disease" in children, of whom 12 were colored. Judging by his records and his roentgenograms, it appears probable that most of these are really B_1 deficiency cardiac enlargements! There is no question about the enlarged hearts in the illustrations in his article, and some of the children responded characteristically to a diet containing liberal amounts of thiamin.

Does cardiac enlargement develop in cases of mild or subclinical beriberi? We do not believe it does. The enthusiasm for ascribing all kinds of mild clinical disturbances to vitamin deficiency has reached a point where fully two-thirds of patients

TABLE II: REVERSIBLE CARDIAC ENLARGEMENT IN THIAMIN DEFICIENCY (BERIBERI)

(Changes in transverse diameter of heart (T.D.) as measured on 6-foot films, following thiamin administration, and period of time between roentgen examinations)

Case	T.D. of Heart before and after Thiamin		Difference	Period
Author's Series	cm.	cm.	cm.	days
1. G. B.	18.0	15.0	3.0	28
5. W. L.	20.0	18.0	2.0	13
6. M. G.	15.3	12.2	3.1	12
7. H. A.	15.5	11.0	4.5	20
8. E. P.	14.5	13.5	1.0	21
9. O. N.				
1st entry	15.0	13.0	2.0	9
2nd entry	15.5	12.7	2.8	12
10. C. S.	15.0	13.5	1.5	5
11. E. G.	16.0	12.0	4.0	98 (3¼ mo.)
12. R. McM.	17.5	13.1	4.4	28
13. O. P.	16.5	14.5	2.0	6
14. P. B.	16.0	13.5	2.5	14
AVERAGE			2.7	15*
Schretzenmayr's Series (Selected)				
1.	18.3	12.8	5.5	28
2.	14.9	12.5	2.4	26
5.	15.9	14.0	1.9	8
9.	15.1	13.0	2.1	11
11.	15.7	13.8	1.9	11
12.	19.0	14.3	4.7	7
AVERAGE			3.1	15

* Excluding Case 11, in which follow-up films were delayed.

seen in clinical practice are potential "subclinical vitamin disorder" cases. Symptoms of slight weight loss, asthenia, anorexia, irritability, easy fatigability, heartburn, impaired memory, etc., are so common that we cannot ascribe them exclusively to vitamin disorders. Furthermore, some investigators believe that mild degrees of vitamin deficiency are *not* common in the ordinary population (Clendenning, 3, in contrast to Lepore *et al.*, 10, 16). It is possible that simple methods for the determination of urinary vitamin B levels will some day be available and aid in settling the question in most cases.

DIFFERENTIAL DIAGNOSIS

The diagnosis of cardiac disease due to thiamin deficiency is suggested by the advent of congestive failure presenting few or several of the conspicuous features de-

TABLE III: CASES OF D AND C DEFICIENCY

Case	Sex	Age	Diagnosis: Clinical and X-ray
1. P. d. S.	M.	7 mo.	Rickets, moderately severe
2. J. D. L.	M.	6 mo.	Rickets, mild
3. J. G.	M.	8 mo.	Rickets, severe (Fig. 2)
4. B. A.	M.	8 mo.	Rickets, mild
5. J. W.	M.	8 mo.	Scurvy, mild
6. C. L.	F.	1 year	Rickets and scurvy, severe (Fig. 3)
7. F. L.	M.	1 year	Rickets and scurvy, moderate
8. C. C.	F.	11 mo.	Rickets and scurvy, severe
9. J. D.	M.	8 mo.	Rickets and scurvy, mild
10. J. P.	M.	1 year	Rickets and scurvy, severe
11. E. C.	F.	44 years	Scurvy. This patient had eaten only boiled milk and white bread for two years because "everything else caused hot flashes." Heart and lungs negative (clinical and x-ray examination). Severe bleeding gums and moderate pains in legs. Response to cevitamic acid prompt.
12. G. M.	F.	47 years	Scurvy. This patent had eaten "almost nothing" for three years because of epigastric pain. Peptic ulcer for ten years, with five abdominal operations (gastro-enterostomy, gastrocolic fistula, enteric obstruction, etc.). Heart negative (clinical and x-ray examination). Severe bleeding gums and weakness. Developed pneumonia and died after three weeks.

lineated above, the absence of signs of a valvular lesion, hypertension, or thyrotoxicosis, and a history pointing to predisposing factors as discussed previously. The diagnosis is confirmed (and indeed is often first suggested) by serial roentgen examinations and response to treatment.

The roentgen differentiation of thiamin-deficiency cardiac enlargement from that due to arteriosclerotic or hypertensive heart disease, myxedema, arteriovenous fistula, and subacute bacterial endocarditis, can best be made by serial examination in conjunction with specific medication. Careful fluoroscopic examination will be of assistance in many cases, since the thiamin heart shows feeble pulsations, in contrast to the heart in hypertensive and arteriovenous fistula conditions. However, poor pulsation is also seen in the heart of severe coronary disease, myxedema, and subacute endocarditis, and differentiation from these lesions and from small pericardial effusions cannot, therefore, readily be made by roentgen examination alone.

CASE REPORTS

I. Patients with D and C Deficiency, Alone or in Combination

None of these patients showed evidence of cardiac enlargement or failure. For details of this group see Table III.

II. Patients with B_1 Deficiency

Most of the patients with B_1 deficiency showed evidence of cardiac enlargement and failure.

CASE 1: G. B., male, 35 years, grocery clerk, was admitted April 15, 1939, having been drinking heavily for six months. His diet had been grossly inadequate for over two years, and he had eaten nothing for a week prior to entry. For two weeks he had suffered severe dyspnea and increasing swelling of the legs, paralleling which was a weight gain of 15 pounds.

On examination, the fundi were normal, neck veins distended, heart markedly enlarged, rate 120/min.; a loud gallop rhythm was present. The blood pressure was 130/106. There were right hydrothorax and edema of the legs. The calves were tender, ankle jerks absent. Serum protein was 5.9 per cent. No treatment was given other than bed rest, result-
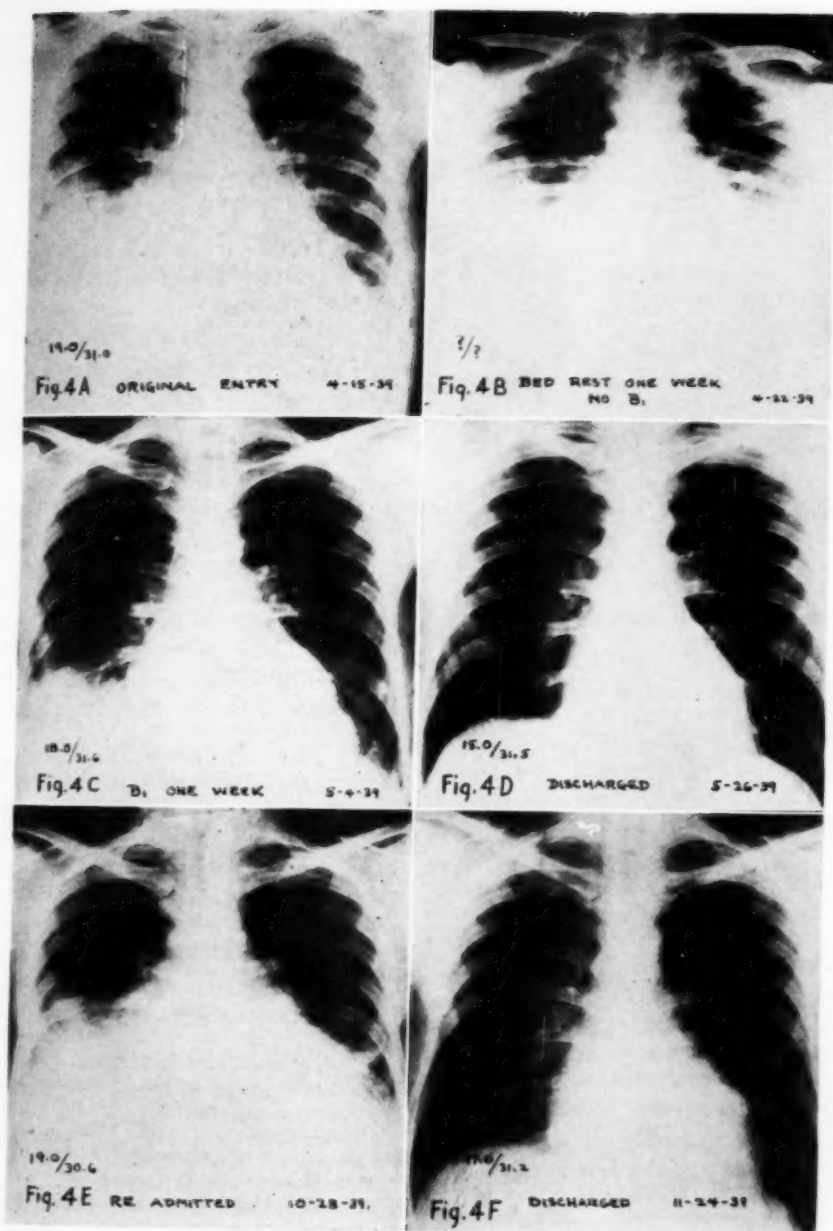
Fig. 4. Case 1, thiamin deficiency series: G. B., male, 35 years.

4A and 4B. Cardiac enlargement, with marked pulmonary congestion and edema or infarct at right base. No improvement after bed rest for one week, on ward diet.

4C and 4D. Marked improvement after thiamin parenterally for one week. There was complete clearance of cardiovascular symptoms after three weeks.

4E and 4F. Cardiac enlargement, with pulmonary congestion, recurring after dietary (and alcoholic) irregularities. Complete clearance of signs and symptoms after four weeks thiamin therapy. The patient was discharged well, but repaired promptly to his old ways. He was readmitted and died. Necropsy disclosed typical findings of "beriberi heart."

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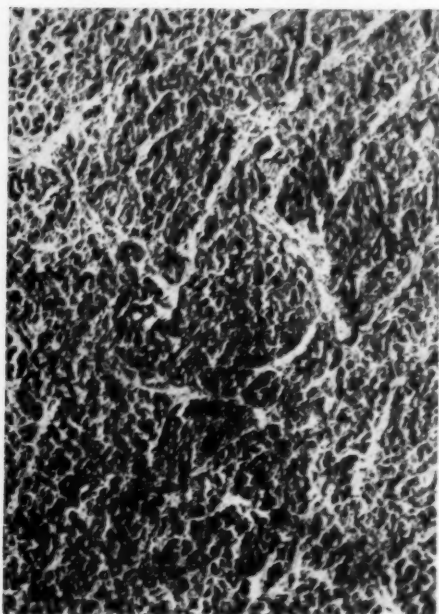
Fig. 5. Case 1: Photomicrograph of cardiac muscle showing many vacuolated fibers (hydropic swelling of muscle) and some small interfascial scars.

ing in the next three days in a weight gain of 10 pounds and increase in the dyspnea. Thiamin administration parenterally was now begun. Within a week there was striking clinical improvement with disappearance of edema and dyspnea, despite an intercurrent pneumonia which yielded to sulfapyridine. The QRS amplitude had returned to normal from the low voltage originally noted, but abnormal T waves persisted. The patient was discharged a month later entirely well.

This patient re-entered the hospital Sept. 27, 1939, having *failed to observe the admonition to refrain from alcohol and adopt a varied diet.* He had gained 26 pounds in the week prior to entry. The physical signs were as before except that the edema was even more marked. On the same therapy as previously he made a complete recovery in two weeks and was again discharged. After an interim episode of edema, which subsided on thiamin at home, a third admission followed on Dec. 26, with the patient in a recurrence more shocking than anything that had been seen previously. Despite parenteral thiamin therapy he died suddenly on Dec. 29.

Necropsy: The heart was enlarged, weighing 650 gm., and showed subendothelial fibrosis, edema, necrosis, and hypertrophy of myocardial fibers (Fig. 5). There was an infarct of the right kidney, generalized passive congestion, and edema. There was no coronary artery disease. Mural thrombi were found.

X-Ray Findings (Fig. 4)

Date	T.D.H./- T.D.Th.[2]	Lungs
4/15	19.0/31.0	Severe congestion; fluid, right base
4/22	Unmeasurable	Severe congestion; fluid, both bases
5/4	18.0/31.6	Clear; small amount of fluid, right base
5/26	15.0/31.5	Clear
10/28	19.0/30.6	Severe congestion; fluid, right base
11/24	17.0/31.2	Clear
12/27	20.0/30.0	Severe congestion; fluid, both bases

Comment: The inability of this personality to profit by bitter experience has furnished us with an example of the inexorable course of this disease when the initiating factors are not eradicated or are permitted to recur. We are further supplied with convincing evidence that beriberi often repeated, or of long duration, can cause cardiac hypertrophy. Though thiamin rescued this man twice, it failed on the third occasion, probably due to the addition of some alteration not so readily amenable to specific therapy.

CASE 2: F. B., male, 70 years, ranch hand, was admitted July 11, 1939, complaining of gradually increasing dyspnea for five years, much aggravated during the last two weeks. His habits as to alcohol could not be learned except that he had been on a nine-day debauch just preceding hospitalization. He had severe diarrhea and symmetrical induration and pigmentation of the skin over the backs of the hands, with a history of solar sensitivity in these areas. The sensorium was clouded. The heart was normal in size, and a systolic murmur only was present. There was no edema. The blood pressure was 114/64.

Death occurred from heart failure five days after admission, thiamin having been given orally for two days.

X-Ray Findings (7/13/39): The heart appeared normal in size. There was moderate passive congestion of the lungs.

Necropsy: The heart showed no other lesion than hydropic degeneration. There was striking evidence of chronic heart failure in the liver and lungs. Mild generalized arteriosclerosis was present, but with no significant changes in the coronary arteries.

[2] Throughout these case reports the letters T.D.H. mean transverse diameter of heart, in cm., measured on a six-foot roentgenogram made in inspiration. The letters T.D.Th. mean transverse diameter of bony thorax as measured on the same film, at the level of the top of the left diaphragm.
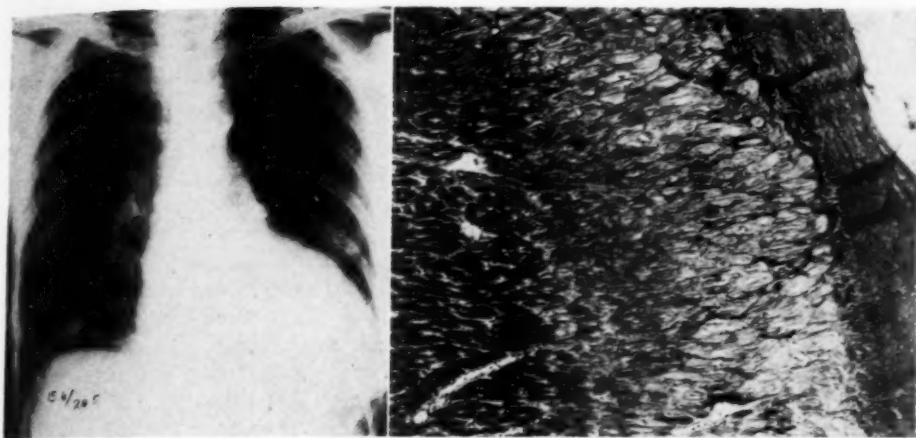
Figs. 6 and 7. Case 3, thiamin deficiency series: E. P., female, 59. Cardiac enlargement and slight pulmonary congestion. This patient had peripheral neuritis and other evidences of thiamin deficiency. She died during an attack of angina about one month later. Necropsy disclosed typical "beriberi heart" changes. The type of enlargement noted by x-ray in this case is quite unusual, most cases showing generalized enlargement. The photomicrograph of cardiac muscle shows hydropic swelling of the muscle fibers. Other sections showed swelling of collagen and perivascular edema.

Comment: This is an instance of the type of cardiovascular beriberi, previously reported by others, in which the heart is not enlarged. A clinical diagnosis of beriberi heart could not be made with assurance, but might have been made presumptively on the physical evidence of deficiency of other factors of the B complex (nicotinic acid), associated with absence of other etiology for heart failure. The case emphasizes the vital importance of the characteristic shrinking of the cardiac silhouette following appropriate therapy in clinching a diagnosis of beriberi heart, and the uncertainty which may attend the lack of this valuable sign.

CASE 3: E. P., female, 59 years, seamstress, was admitted Jan. 18, 1939. There was no history of alcoholism but the patient had lived alone many years, preparing all her own food. Two years before, she had undergone an episode of heart failure marked by dyspnea, edema, and palpitation, with partial recovery after six weeks in bed, the dyspnea, however, persisting. Three months before admission she suffered another attack of failure, and since then dyspnea had been extreme. She entered because of a left hemiplegia. Examination showed, in addition to the neurological findings, a normal blood pressure, enlarged heart, blowing systolic murmur, and bundle-branch block by electrocardiogram. There was extensive peripheral edema. The hemiplegia showed indications of rapid amelioration but on

March 4, 1939, anginal pain and prostration suddenly developed. The patient failed to rally; no treatment other than rest and ward diet was offered, and death occurred on March 18.

X-Ray Findings (1/24/39): Heart enlarged, chiefly to the left (15.6/24.5); slight hilar congestion with small amount of fluid at right base (Fig. 6).

Necropsy: Hydropic degeneration of myocardium; extensive ventricular mural thrombosis (Fig. 7). Infarcts of the brain, lungs, and kidneys were found as embolic sequels to the mural thrombi. The coronary arteries were normal save for a few yellowish plaques.

Comment: This case history calls attention to a social situation which often eventuates in deficiency disease of one sort or another. The man who "batches," or the lone spinster who does her own cooking, is liable to narrow and inappropriate food selection, more particularly as advancing years engender a gustatory indifference.

CASE 4: A. M., male, taxi driver, complained of severe pain in legs and arms for four months. He had been on an exclusive milk diet for six to twelve months, for no known reason. Shortly after entry, advanced polyneuritis developed, with bilateral foot drop, and, after an attack of erysipelas, and despite oral thiamin, decompensation appeared, the heart enlarging under observation, with accompanying gross edema. The blood pressure was moderately elevated (140/100). Electrocardiogram showed

inverted T_1, flat T_2. The blood protein was 6.5 per cent. At no time was there evidence of a valvular lesion. On May 10, 1936, empyema developed and death occurred ten days later.

X-Ray Findings (4/13/36): Cardiac enlargement (15.2/27.5); passive congestion of the lungs.

Necropsy: There was hydropic degeneration of the heart muscle fibers; otherwise no cardiac disease was found. Empyema and pyelonephritis were present.

Comment: Here the predisposing factor was a dietary notion or fad. That this man contracted a typical beriberi while subsisting for a year exclusively on the "perfect" food, milk, should serve as a warning. Milk is not ordinarily rich in thiamin and in the winter months is often sadly deficient. The lack of response to thiamin by mouth serves to warn us that many patients are unable to absorb this substance from the gastro-intestinal tract, and that it should always be given parenterally when beriberi has developed. The tendency of infections both to precipitate the cardiovascular manifestations of the disease, as well as to initiate circulatory collapse once heart failure is established, is well illustrated here.

CASE 5: W. L., male, 32 years, entered on July 8, 1941, complaining of swelling of the ankles and shortness of breath for five days. There was no past history of syphilis or rheumatic fever, but alcoholism over an extended period was admitted, and there was a distinct likelihood of dietary inadequacy. The patient was orthopneic, the heart was markedly enlarged, the pulse regular at 120, and blood pressure 120/100. The neck veins were distended. The ankles were edematous. The electrocardiogram showed low T waves in standard leads. Careful eye-ground study failed to reveal changes consistent with significant hypertension in the past. On a high-vitamin diet and parenteral administration of thiamin the course was that of a chronic heart failure with periods of mild improvement. The patient unexpectedly became worse and died Nov. 1, 1941.

X-Ray Findings

Date	Heart		Lungs
7/10	Enlarged	(20.0/33.5)	Passive congestion; fluid, right base
7/23	Smaller	(18.0/33.0)	Lungs clear
9/3	Larger	(20.0/33.5)	Slight congestion and hydrothorax
10/28	Enlarged	(21.0/33.5)	Severe congestion; much fluid on right

Necropsy: The heart weighed 420 gm. and was greatly dilated. There was extensive hydropic degeneration of the muscle fibers and nothing in the heart or elsewhere to indicate other etiology for the failure than beriberi.

Comment: It is difficult to explain the lack of response to specific therapy in this man. It is known that beriberi can result in cardiac hypertrophy. Other rare causes of cardiac enlargement and failure were conscientiously considered, and ruled out by lack of pathological evidence. The cardiac hypertrophy permits the assumption that in this case prolonged thiamin deficiency had resulted in irreversible myocardial changes.

CASE 6: M. G., female, 33 years, housewife, was admitted to Stanford Hospital on the service of Dr. David Rytand on March 9, 1938, complaining of edema for three weeks. Her past history was negative except for psychopathic trends, which had been exaggerated for the past year. Her dietary history for that period was of great interest. For the first three months of the year she confined her intake exclusively to boiled eggs. For the second three months she ate nothing but bakers' snails. For the third three months her diet consisted solely of mush, and for the last three months she had eaten only honey. On this régime she lost some 50 pounds but remained free of edema and other cardiac symptoms. Three weeks prior to entry she enlarged the variety of ingested foods somewhat, consuming considerable amounts of bread, cake, rice, and a few eggs. Almost at once she became edematous, gaining 30 pounds during this short period. That at no time in the preceding year had she eaten meat, fruit, vegetables, or whole grain cereals was corroborated by members of the family. She became markedly dyspneic and orthopneic developed three days before hospital entry. She had never suffered from neuritic pain.

Examination revealed edema extending to the chest wall; the neck veins were distended; the heart was enlarged and had a gallop rhythm, but no murmurs were heard. There was no objective evidence of peripheral neuritis. The blood pressure was 150/110; the venous pressure 21 cm. NaCl. The circulation time (decholin) was 10.2 seconds; vital capacity 1,500 c.c., plasma protein 4.5 per cent. The electrocardiogram showed a sizable Q-3 and inversion of T-4.

The patient was put on a high-vitamin, high-protein diet on entry. Beginning four days later, 4,000 units of B_1 were injected subcutaneously daily. Within one week after the inauguration of parenteral vitamin administration the patient was clinically well. The edema had entirely subsided, vital capac-
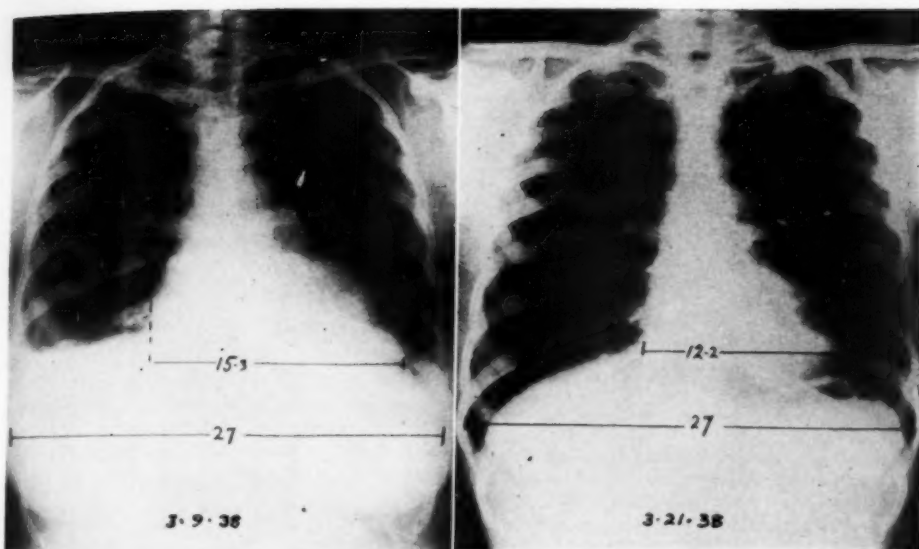
Fig. 8.   Case 6, thiamin deficiency series: M. G., female.   The enlarged heart shrank 3.1 cm. in transverse diameter in twelve days, on thiamin chloride.   The passive congestion of the lungs, pleural edema, and associated findings showed similar improvement.

ity was 2,300 c.c., blood pressure 120/75, and the cardiac shadow had decreased to normal dimensions; the plasma protein had risen to 7.7 per cent; the electrocardiogram now showed a very small Q-3 and an upright T-4.

X-Ray Findings (Fig. 8)

Date	Heart	Lungs
3/9	Enlarged (15.3/27.0)	Slight pulmonary congestion
3/21	Normal in size (12.2/27.0)	Lungs clear

Comment: This case history illuminates two important features in connection with the physical changes wrought by thiamin deficiency. It will be noted that despite the most gross dietary imbalance imaginable, extending over a period of a year, this woman did not develop outspoken evidence of athiaminosis, the reason being that her intake was inadequate not only in thiamin content, but also calorigenically. She was, during this time, suffering more from starvation than a specific deficiency. Immediately on the adoption of a high-caloric intake, however, in foods which added nothing to the thiamin intake, the thiamin-non-fat calorie ratio was severely upset and evidence of cardiovascular beri-beri appeared at once. The patient is representative of a group who predispose themselves to this disease because of dietary notions.

CASE 7: H. A., male, 56 years, entered on Dec. 31, 1939, with a history of infrequent employment and scanty diet. He complained of exertion dyspnea over the past two years and edema for ten days. For five years he had had mild to moderate precordial pain on effort, and had suffered many attacks of paroxysmal dyspnea, several of them at night. He had been given digitalis for some time before admission, without benefit. The patient was orthopneic; the neck veins were markedly distended and the heart was enlarged. There was neither valve lesion nor hypertension (blood pressure 110/70, and normal eye grounds). The liver was enlarged. Peripheral neuritis was present. The electrocardiogram showed large P waves, low T waves in standard leads, and absent Q-4. A right hemiplegia developed in the hospital, but cleared up rapidly. With rest and ward diet the edema and severe dyspnea abated within two weeks and the cardiac enlargement receded. The electrocardiogram showed no change.

X-Ray Findings

Date	Heart	Lungs
1/9	Enlarged (15.5/28.2)	Fairly severe hilar congestion
1/29	Normal (11.0/27.5)	Lungs clear
9/16	Normal (11.2/28.4)	Lungs clear

Comment: There is abundant evidence that this man suffered from arteriosclerotic heart disease for a period of years, on which had been superimposed a deficiency element. The latter characteristically was unaffected by digitalis but responded to the vitamin content of a ward diet. This would confirm the opinion that orally administered vitamins as such, or as they occur in food, are probably more efficiently absorbed by the person whose intestinal tract is not the site of alterations produced by acute or chronic alcoholism, and that in the latter poor absorption may vitiate the thiamin effect.

CASE 8: E. P., male, 39 years, an alcoholic who had been on an obviously deficient diet, entered the hospital March 15, 1939, complaining of moderate dyspnea, very marked edema and severe pain in the legs. The heart was enlarged, pulse rate rapid, and peripheral neuritis was present. There were no murmurs nor was there hypertension. The fundi were normal.

X-ray examination was made on entry. For the following four days the patient was given a Spies thiamin-free diet, at the end of which period a second film was made. The same diet was then continued but thiamin was given parenterally and orally. A third film was taken eighteen days later, at which time the edema and other signs of failure had subsided. The blood protein on entry was 5.7 per cent; four days later, 5.6 per cent, and at the time of the third film 7.2 per cent.

X-Ray Findings

Date	Heart	Lungs
3/16	Slightly enlarged (14.5/28.0)	Moderate hilar congestion
3/20	Slightly enlarged (14.5/27.5)	Severe hilar congestion
4/7	Normal size (13.5/27.5)	Lungs clear

Comment: The course of this case shows lack of response during the first period, without thiamin, and the remarkable effect on the urinary output and edema in the second period, when thiamin was given.

CASE 9: O. N., male, 55 years, entered the hospital Jan. 31, 1938, with severe edema of legs, penis, and scrotum and moderate dyspnea. He had been drinking one pint of spirits daily; food intake was not ascertainable. The heart was enlarged, with gallop rhythm; blood pressure 128/108. The carotid sinus reflex was hyperactive. Treatment consisted in digitalis and yeast, with remarkable results

in ten days, the general improvement being well reflected in the roentgenograms. After discharge the patient remained unemployed and well for four months. He then became the recipient of public largesse in the form of a W.P.A. job and with the funds so provided was enabled to resume his drinking. The latter was abruptly terminated by a recurrence of gross edema and moderate dyspnea, and he was readmitted Nov. 9, 1938. The heart was again enlarged, the gallop had returned, and the pulse was 110 and irregular. There were no significant murmurs and the blood pressure was normal. The liver was enlarged, the carotid sinus hyperactive; the calves were tender, and knee and ankle jerks absent bilaterally. Electrocardiography revealed 3:2 heart block. Serum protein at this time was 5.8 per cent.

On failure to improve after a week of rest and ward diet, the patient was given thiamin and yeast orally, with resulting rapid amelioration of all symptoms and signs. He was discharged well on Dec. 6.

X-Ray Findings

Date	Heart	Lungs
2/2	Normal size (15.0/32.0)	Slight hilar congestion; small amount of fluid in right base
2/11	Smaller (13.0/31.2)	Lungs clear
11/17	Enlarged (15.5/31.6)	Passive congestion of lungs
11/29	Normal size (12.7/31.0)	Lungs practically clear

Comment: This case reflects the rapidity with which a thiamin deficiency may give rise to grave cardiovascular impairment, and further illustrates the tendency for successive attacks to become increasingly severe, suggesting that recovery is perhaps not always as complete as it appears to be, each attack leaving a residuum of permanent damage.

CASE 10: C. S., male, 39 years, alcohol addict with a history of irregular, infrequent eating for three months, entered the hospital on March 9, 1939, complaining of dyspnea and edema for seven days. The physical examination showed marked cardiac enlargement, tachycardia, severe edema of legs and particularly of the scrotum. There were no murmurs nor arterial hypertension. The electrocardiogram showed R.A.D. Peripheral neuritis was moderately advanced. On large doses of B complex (Betaxin and yeast) by mouth, diuresis immediately developed, with disappearance of edema in five days. Two weeks after admission all signs except the neuritis had disappeared and the patient was discharged on March 24.
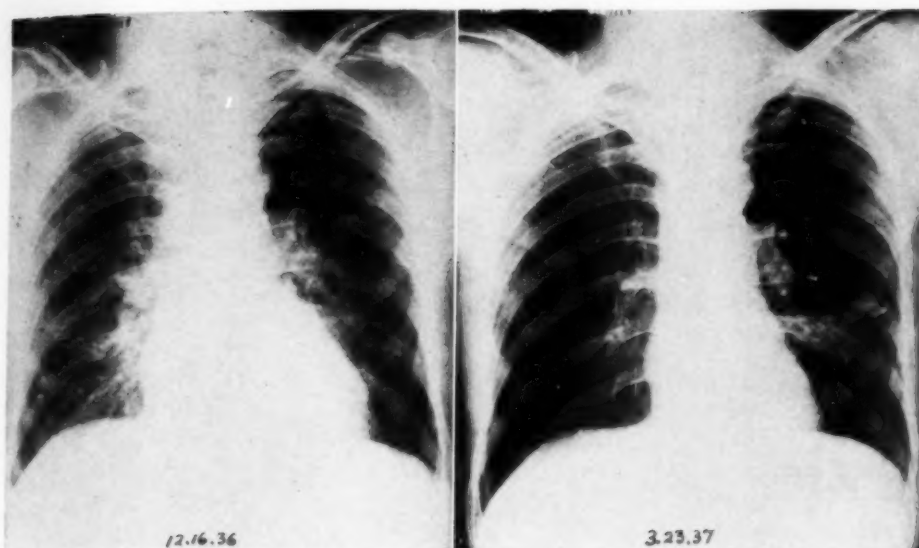
Fig. 9 Case 11, thiamin deficiency series: E. G., male, 44. Enlarged heart, with moderate pulmonary congestion. Cardiac diameter shrank 4 cm. in less than twelve weeks, on thiamin therapy.

X-Ray Findings

Date	Heart	Lungs
3/10/38	Enlarged (15.0/27.0)	Severe passive congestion
3/15/38	Smaller (13.5/26.0)	Slight congestion
3/24/38	Unchanged (13.5/26.0)	Lungs clear
9/ 4/39	Normal (12.0/25.0)	Lungs clear

CASE 11: E. G., male, 44 years, was admitted Dec. 12, 1936, complaining of pain in the legs for the past month, aggravated by walking. He had consumed a pint of whisky daily for a period of years. For six months he had experienced occasional edema and dyspnea. Physical examination showed slight distention of neck veins, slight enlargement of the heart to percussion, a harsh systolic murmur over the precordium (but no diagnostic murmurs), loud presystolic gallop, edema to mid-thighs, blood pressure of 100/50, tender calves. Electrocardiogram was normal. The diagnosis was arteriosclerotic heart disease (beriberi not having been considered!). On rest and ward diet symptoms cleared up in a month and the patient was discharged. He returned six weeks later with pneumonia. There was at this time no cardiac symptomatology. Beriberi was now suspected in retrospect and check-up x-ray examination showed a cardiac silhouette of normal dimensions. The patient succumbed to the pneumonia and at autopsy no arteriosclerotic disease was found in the heart.

X-Ray Findings (Fig. 9)

Date	Heart	Lungs
12/16/36	Enlarged (16.0/30.0)	Moderate pulmonary congestion
3/23/37	Normal size (12.0/29.0)	No passive congestion (but patch of pneumonitis present in left base)

CASE 12: R. McM., male, 36 years, admitted on Dec. 8, 1936, complaining of increasing weakness of the legs, dyspnea, cough, and anorexia. He admitted drinking 3 to 4 pints of fortified wine daily for 3 months. The heart was enlarged, and there was a gallop rhythm but no diagnostic murmur; edema was extensive. Electrocardiogram showed myocardial damage of no specific nature. Blood pressure was normal. The classical signs of peripheral neuropathy were present in the lower extremities, namely, loss of superficial touch, loss of pain and position sense, with aggravation of deep pain, and absent knee and ankle jerks.

The patient was placed on rest, digitalis, and ward diet for twenty days without change in his condition. Thiamin was then commenced by the oral route and fifteen days later the edema had dissipated, and the heart had returned to normal size.

X-Ray Findings (Fig. 10)

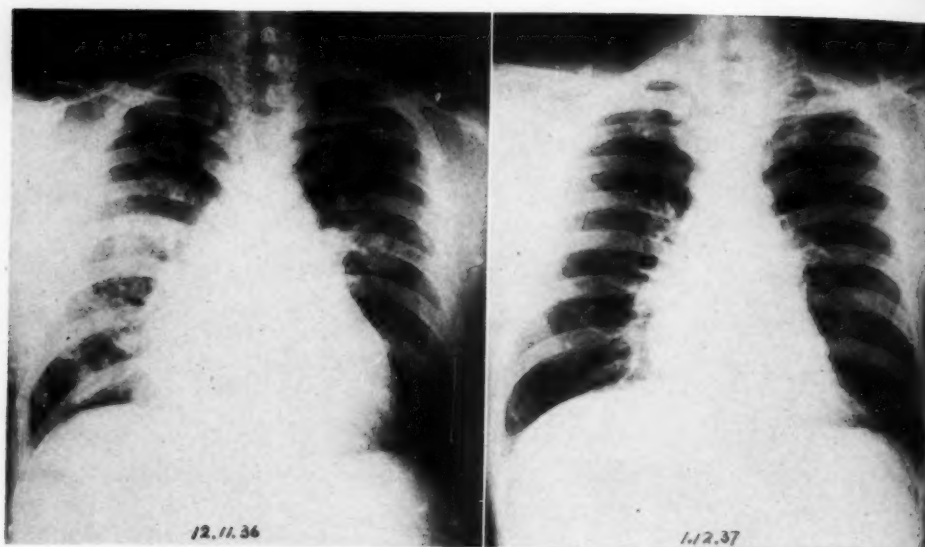| Date	Heart	Lungs
12/11/36	Enlarged (17.5/29.5)	Moderate pulmonary congestion or edema
1/12/37	Normal size (13.1/29.5)	Lungs clear

Fig. 10. · Case 12, thiamin deficiency series: R. McM., male, 36. Enlarged heart with moderate pulmonary congestion or edema. Transverse diameter of heart shrank 4.4 cm. in 4 weeks with thiamin therapy.

CASE 13: O. P., male, 45 years, was admitted on July 23, 1940, with a history of seven months of scanty and irregular diet coupled with excessive drinking. The complaints were dyspnea, swelling to the hips, tender calves, and burning, tingling feet for four days. Six months previously the patient had experienced a similar episode in milder form, which subsided with ten days' rest in bed. The heart was enlarged; there was a loud systolic murmur but no evidence of valvular defect. Edema extended to the scapular angles. Blood pressure was 108/55. The calves were very tender, and a pellagrous dermatitis covered the feet. Serum protein was normal. Thiamin was given parenterally at once, with dramatic results; the mobilization of fluid was so rapid that three days later a pulmonary edema developed and the blood pressure rose to 165/125! In the next four days the patient lost 30 pounds, and ten days after entry all signs of heart failure had abated and the blood pressure was 128/84. The peripheral neuritis, however, persisted in an aggravated form. The patient was discharged Sept. 16, 1940, only to return May 1, 1941, with a story of continued faulty eating and excessive drinking in the interim. He was again dyspneic and edematous, the heart was enlarged, and a cardiac death ensued on the day of admission. A curious observation was a white cell count of 63,000, with 97 per cent neutrophiles. Permission for autopsy was not obtained.

X-Ray Findings

Date	Heart	Lungs
7/24	Slightly enlarged (16.5/32.0)	Slight hilar congestion
8/30	Normal size (14.5/29.0)	Hilar congestion diminished
9/3	Negative (14.5/32.0)	Lungs clear

CASE 14: P. B., male, 49 years, sheet-metal worker, was admitted Aug. 15, 1941, complaining of dyspnea for three days and edema and leg pains for two weeks. He was a fortified wine habitué, having consumed one or two bottles of muscatel daily for the past two years. His diet consisted almost entirely of meat, usually in the form of stews, and macaroni. Diarrhea had its inception three weeks before admission.

Examination showed the presence of pellagrous skin changes over the backs of the hands, an enlarged heart with a systolic but no other murmurs, and edema to the mid-thorax, disproportionately involving the scrotum and penis. The blood pressure was 142/68, Duroziez's sign was positive, and the pulse 120, regular. Peripheral neuritis was advanced to the stage of absent deep reflexes. Thiamin was started parenterally at once. In six days the edema had been shed and the blood pressure now showed an elevation to 158/82, characteristic of this stage of recovery. By Aug. 30 recovery was complete.

X-Ray Findings

Date	Heart	Lungs
8/16	Enlarged (16.0/29.5)	Moderate pulmonary congestion
8/30	Normal size (13.5/29.0)	Lungs clear
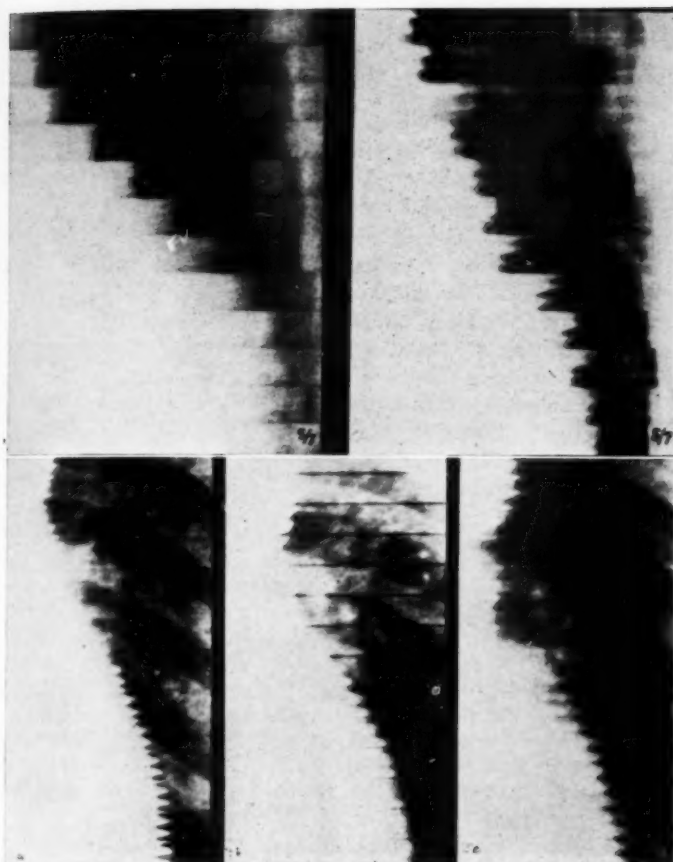
Figs. 11 and 12. Roentgenkymograms, showing effect of thiamin therapy in thiamin deficiency.

Fig. 11 (above) is from a case of severe thiamin deficiency (male, 23 years). The roentgenkymograms were made before and after thiamin therapy (2 months). Cardiac pulsations feeble in left figure (when patient was in acute cardiac failure—"Shoshin state"), and much improved in right figure (Iwasaki).

Fig. 12 (below) shows roentgenkymograms made before, during, and after experimental B₁ deficiency in a male of 25 years. The middle film was made after about two months on a deficient diet (Iwasaki).

SUMMARY

The authors have reviewed the diagnosis and differential diagnosis of vitamin-deficiency cardiovascular conditions. It is their impression that the majority of cases of true cardiovascular disorders in vitamin-deficiency states are due to severe thiamin deprivation. The heart shows generalized enlargement and diminished pulsations. Response to thiamin therapy is usually prompt and satisfactory, the classical symptoms of cardiac failure abating rapidly and the heart diminishing greatly in size within two weeks. In some cases, however, in which perhaps irreversible cellular changes have taken place, little improvement occurs even on adequate diet and rest. These cases are usually terminal or are complicated by myocardial damage of other origin.

There are no pathognomonic roentgen findings in vitamin-deficiency cardiovas-

cular disease. However, the finding of an enlarged, poorly contracting heart and mild pulmonary congestion in an adult without evidence of valvular disease should raise the possibility of thiamin deficiency in the mind of an alert radiologist, in addition to the other well known causes of such findings. Clinical exclusion of hypertensive disease increases the possibility of the enlargement being "avitogenic." Prompt diminution in cardiac size and disappearance of congestion under thiamin therapy virtually clinch the diagnosis.

Cardiac enlargement in vitamin-deficiency conditions such as scurvy and rickets is apparently nearly always, if not always, due to an associated but masked thiamin deficiency.

Fourteen cases of thiamin-deficiency cardiovascular disease (beriberi hearts) in adults are reported. Two cases of cevitamic acid deficiency in adults and one in an infant, 5 cases of combined cevitamic acid and vitamin D deficiency in infants, and 4 cases of D deficiency alone are also reported. In none of these "non-thiamin" cases was there any definite evidence of cardiovascular disorder.

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Significance and Management of Radiation Injuries[1]

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IT MIGHT HAVE been expected that increasing familiarity with the biological effects of x-rays and radium, more thorough knowledge of the dangers ensuing from overdosage with these physical agents, and rapid progress in the technical development of x-ray equipment, as well as the marked improvement of means for radiation protection and better medical training in general, would have resulted in decreasing to a minimum the incidence of cutaneous injuries by x-rays and radium. Unfortunately this expectation has not materialized, and papers published in recent years, as well as cases in our own experience, give ample proof that x-ray injuries are seen with increasing frequency. Ironically and tragically the growing number of victims of excessive radiation includes not only patients but more and more physicians as well. In support of this contention I might cite, among others, the publications of Saunders and Montgomery (6), who reported on 259 cases of radiation dermatitis in 1938; Duffy's paper (1), published in 1939; Leddy and Rigos (2) whose last report appeared in May 1941; and a number of papers on this subject which I published between 1930 and 1940 (8). All of these reports reveal a significant increase in the proportion of physicians among the entire group injured by radiation.

Since the analysis of cases which concern the medical profession itself is quite instructive, I should like to present a few details about 70 patients with radiation injuries referred to the Tumor Clinic of Michael Reese Hospital in Chicago in the last three years. Of this group of 70 patients, only 30 received their injuries as a result of *treatment* with x-rays and radium, the remainder having been injured in the course of *diagnostic* or *technical* work with these agents. Only 14 of the 30 treated patients had received their treatment for malignant tumors; the others had been given x-ray therapy for various skin conditions, particularly acne, hyperhidrosis, removal of hair, or other cosmetic purposes. Thirty-five patients, or exactly half of the total, were physicians or persons professionally engaged in x-ray work. This is a rather unusually large percentage of physicians, greater than in any other reported series. It may be explained in part by the fact that these physicians, aware of the possibility of successful therapy for their injuries, came to Chicago from an area much greater than that which ordinarily furnishes our patients.

Eighteen of these physicians were general practitioners; of the remainder, 4 were surgeons, 3 radiologists, 2 pediatricians, 4 dentists, and 4 physicists. The small number of radiologists is of special interest, particularly since these men had been working in their specialty for a long time and had been exposed to radiation from twenty to forty years, which easily explains the occurrence of their injuries. Of the remaining 32 physicians and physicists, only 4 were injured by therapeutic measures; in the other 28 the injuries followed diagnostic or technical x-ray work. Four traced their injuries to exposure under the fluoroscope while attempting the removal of foreign bodies; the radiodermatitis of the 4 dentists developed on the fingers which they used to hold the film in the patient's mouth while taking a dental roentgenogram. The remaining 20 physicians were accustomed to do x-ray diagnostic work without special protection or, as in the case of the pediatricians, were in the habit of holding babies before the fluoroscopic screen. Some could not offer any more specific explanation than that they had done x-ray diagnostic work in

their offices. Frequently they were not even familiar with any of the technical details of such work.

If these figures are of any significance, as they appear to be since they are confirmed by the experience of others quoted above, we may draw the following conclusions as far as radiation injuries to the medical profession are concerned:

(1) Injuries to physicians encountered following x-ray or radium *therapy* are uncommon and are usually not severe. In most instances they follow treatment for malignant tumors.

(2) The number of *radiologists* involved is apparently small. This is as would be expected, in view of their better training, their thorough knowledge and familiarity with the biological effects of x-rays and radium, and consequently their care in handling these agents.

(3) The majority of the physicians received their injuries following *x-ray diagnostic work*, a fact which may be explained by a variety of factors including unsatisfactory equipment, insufficient protection, inadequate knowledge of the dangers involved, or simple carelessness, since in some instances the injurious effects are unquestionably due to inexcusable disregard of protective measures.

As far as the non-professional patients are concerned, only 6 of this group of 35 were treated by trained radiologists and 4 of these 6 received their treatments for malignant tumors. Among the remainder are 9 patients who were injured following diagnostic procedures. Four of them underwent fluoroscopy for the removal of foreign bodies and the rest were exposed to prolonged fluoroscopy for other purposes. In no instance was a radiologist responsible for injuries occurring in the course of diagnostic procedures. It does not seem necessary to enlarge on this point.

Radiation injuries are important for different reasons: (1) They result from medical intervention and therefore may constitute grounds for lawsuits for malpractice. (2) Although they may become evident immediately or shortly after ex-

posure to radiation, they often appear at a later time, sometimes after a lapse of many years. (3) They show a considerable resistance to all therapeutic efforts and the pain, which is often agonizing, may last for years. (4) They eventually lead to the development of malignant tumors in the irradiated injured area. For these reasons a short description of the clinical appearance and the clinical course of radiation injuries seems to be justified.

Radiation injuries of the skin occur invariably at sites where an overdose of x-rays or the gamma rays of radium has been administered. The lesions are always limited to the field of radiation, frequently with sharp borders separating them from the adjacent healthy tissue. Without going into details already familiar, it need only be mentioned that we differentiate between acute or subacute injuries and late injuries which appear months or years following the irradiation. It is possible that the acute lesions never completely heal and after many years present the picture of late injuries. Acute radiation injuries are usually compared with thermal skin burns and designated as radiation "burns" or radiodermatitis of 1st, 2d, and 3d degree. The late injuries show different stages and correspondingly different appearances. They may consist in nothing but dryness or a slight degree of atrophy of the skin, but usually there is a patchy local loss of pigment with deep pigmentation of adjacent areas. Most frequently telangiectasis and sclerodermatic thickening of the skin are the complications seen, followed by formation of hyperkeratoses or ulcerations. These ulcerations, which are extremely painful, exhibit a tendency to refuse to heal, increase in size, and may eventually become practically uncontrollable. The greatest danger of such radiation injuries is the development of cancer which may remain stationary for a considerable time but eventually metastasize and lead to death. The fate of almost the entire first generation of radiologists who became victims of radiation cancer is too well known to need discussion.

The question as to why these late ulcerations following the use of x-rays or gamma rays of radium are so resistant to therapy has never been answered satisfactorily. There is no doubt that the poor circulation and consequently the insufficient blood supply to the areas involved account largely for this resistance. According to the experiments of Rost (5) the impairment of the blood supply following excessive irradiation is initiated by the selective destruction of the endothelial cells of the capillaries, whereas Ricker (4) assumes that the nerves of the capillary walls are first destroyed and consequently the capillaries themselves degenerate. However this may be, there is no question that the lack of a spontaneous tendency to healing and the resistance to any kind of therapy are largely due to the destruction of the capillary system.

In order to treat these lesions effectively, the circulation must be restored. With this necessity in mind, it is easy to understand why the methods of treatment generally used in skin burns, which affect only the superficial layers of skin, are not effective in the treatment of radiation injuries, and it is not surprising that extensive use has been made of therapeutic methods aiming toward a more systemic effect. Periarterial sympathectomy, as recommended by Leriche (3), has been attempted, salt-free diets have been employed, and non-specific protein therapy has been used, as well as permanent water baths over prolonged intervals of time. Each of these local and general methods of treatment, alone or in combination, has occasionally been followed by good therapeutic results in an individual case. Until recently, however, there was no method of treatment for these serious radiation injuries which could be expected to be generally successful.

In some instances where circumscribed hyperkeratosis is the main feature, destruction of the lesions by surgical diathermy is an effective method of treatment. For deep ulcerations, grafting or other plastic surgery has been successfully em-ployed, but in many instances the grafts do not take and become necrotic in these insufficiently nourished areas. Some years ago treatment with a jelly of *Aloe vera* was recommended for general use in radiation injuries. While we have no personal experience with this method of treatment, we have seen a number of patients whose lesions failed to respond to it and who were cured by the method to be described here.

In 1928 I started to use radon, absorbed in vaseline, for the treatment of x-ray and radium injuries, and during the past thirteen years a large number of patients have been successfully treated. It has been objected that injuries produced by excessive radiation should never be exposed to additional radiation of any kind, but this argument has proved not to hold true for this method of therapy. While we subscribe in general to the above statement, it is to be borne in mind that in using alpha rays we are dealing with corpuscular radiation, and not an energy of wave form as with x-rays and the gamma rays of radium. While it is true that the biological effects of these different kinds of radiation may be similar, we have observed no case in which the application of alpha rays in the form to be described has done any harm to the patient, despite their application to a previously injured and devitalized area.

The source of the alpha rays used in our treatment of radiation injuries is radon, a disintegration product of radium in gas form, which has the same qualities as radium element and is widely used for other therapeutic purposes. More than 90 per cent of its emanation consists of alpha rays. For general therapeutic use the gas is enclosed in special containers (gold seeds or platinum needles), the walls of which absorb practically all of the alpha rays and much of the beta radiation as well. To make use of the alpha rays, a different form of application must be employed. We have chosen as a vehicle plain petroleum jelly or petrolatum, which has the advantage that it absorbs, as Strasburger has pointed out, about nine times as much radon as a similar volume
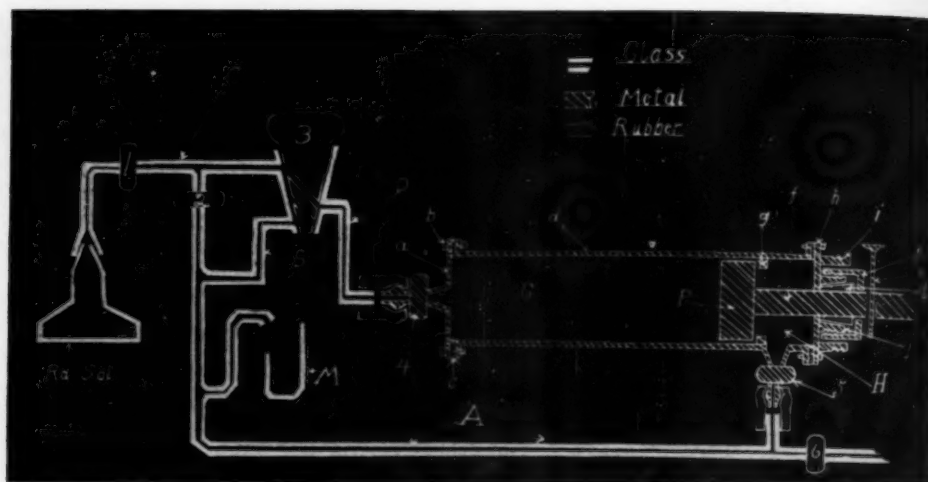
Fig. 1.   Schematic illustration of the radon apparatus employed for collecting radon gas in vaseline ointment
for use in the treatment of radiation injuries.

of air and thirty-six times as much as
water at room temperature. It is thus a
very favorable solvent for radon. While
the penetrating power of alpha rays is
slight and the intact skin would be suf-
ficient to prevent their access to the deeper
tissues, vaseline properly sealed in place
will penetrate through the openings (hair
papillae and excretory ducts of glands) and
eventually reach the capillary system. If
vaseline is charged with alpha rays in the
form of radon these alpha rays will pene-
trate to the same depths. That such an
absorption of alpha rays actually takes
place by the capillary system has been
proved by Strasburger (7). He applied
radon absorbed in vaseline on the surface
of the skin, covering the ointment and
sealing it in such a way that none of the
gas could be inhaled by the person so
treated. Twenty to thirty minutes fol-
lowing such application he was able to
demonstrate radon gas in the expired air.
We ourselves have demonstrated by his-
tologic sections that vaseline applied cuta-
neously and left under proper dressings for
some hours does penetrate into the deeper
layers of the skin. So far we have not been
able to trace the alpha rays themselves in
the deep layers of the skin, though experi-
ments are now under way and the results

of Strasburger's experiments can be ex-
plained only by an absorption of radon
through the capillary system.

For the treatment of radiation injuries
we employ petrolatum charged with radon
in a concentration of about 100 electro-
static units per gram of vaseline, 100 elec-
trostatic units being equal to 0.0364 mcd.
This is an extremely low concentration;
in order to produce an erythema of the
skin about twenty-five times this concen-
tration would be required in a single appli-
cation   The preparation is applied di-
rectly from a container to the area of skin
to be treated and is immediately covered
with a layer of rubber dam or oilcloth of
suitable size sealed in place by adhesive
plaster under which absorbent cotton may
be placed. The adhesive is laid down in
overlapping strips to prevent the escape
of radon gas into the air. This dressing is
left in place for eight hours and is then re-
moved. The treatments are repeated at
intervals of seven days, so that subsequent
applications are always made on the same
day of the week. In the intervals between
treatments the skin must not be irritated
by any medication and is covered by daily
applications of 10 per cent boric acid oint-
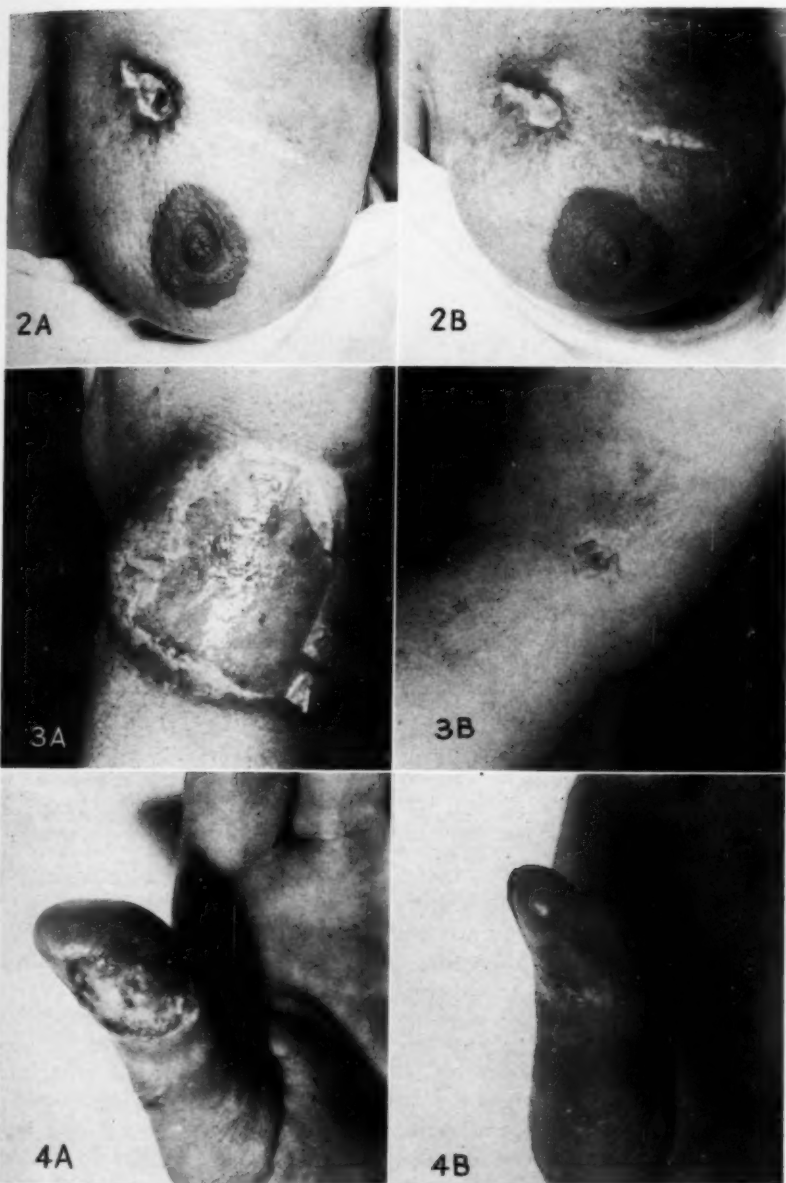ment.

Radon is not a stable product but loses

Fig. 2. A. Roentgen injury of right breast following prolonged x-ray treatment, supposedly for breast carcinoma, no biopsy having been taken. B. Healing with complete epithelialization of the ulcer, following nine applications of radon ointment.

Fig. 3. A. Radiation injury following removal of foreign body under fluoroscopic control. B. Complete healing after fifteen weekly applications of radon ointment.

Fig. 4. A. Radiation injury of thumb following fluoroscopic attempt to remove metallic foreign body. B. Healing with complete epithelialization after a course of radon ointment therapy.

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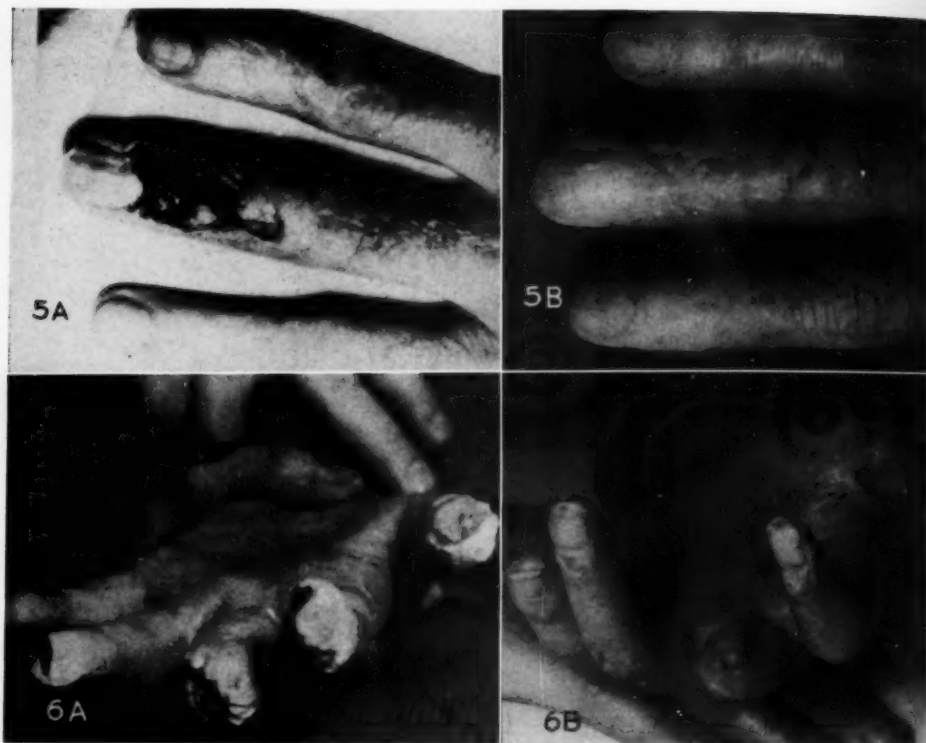
Fig. 5.   A.   Roentgen injury to dorsum of left middle finger of physician, of two years' duration.   B. Complete healing following seventeen weekly applications of radon ointment.
Fig. 6.   A.   Extensive radiation injuries of thumb, index, middle and ring fingers of left hand of physician following fluoroscopic attempt to remove metallic foreign body.   Because of excruciating pain the patient had undergone an amputation of the middle finger at the proximal interphalangeal joint before coming for radon therapy.   B.   Complete healing following twenty-three weekly applications of radon ointment.

16 per cent of its strength every day, its half-value period being 3.8 days. For therapeutic purposes, therefore, it must be collected fresh and dissolved in vaseline, the dose being calculated for the date of use.

There are various ways of preparing this radon ointment, but the principle involved is the same in all. The source of radium emanation is radium element in the form of one of its salts, preferably radium chloride or radium bromide in aqueous solution. Radon is produced continually by such solutions and may be passed into evacuated containers and in these mixed with water or directly with petrolatum. Formerly we used the method of Strasburger (7), by which the radon gas is brought into contact with water and then transferred into wide test tubes, the walls of which are covered with petrolatum. The vaseline, because of its higher absorption rate, absorbs practically all the radon gas originally contained in the water and can be used in this form for therapeutic purposes. The disadvantage of this method is that it involves a double procedure and requires about twenty-four hours for complete absorption of the gas by the petrolatum, during which time 16 per cent of the original concentration is lost.

In the last two years we have employed a different method. The radon ointment is prepared by a semi-automatic pump, which has been described elsewhere (9). The gas is passed into an evacuated container, which is essentially a double chamber pump, and is there mixed with liquid
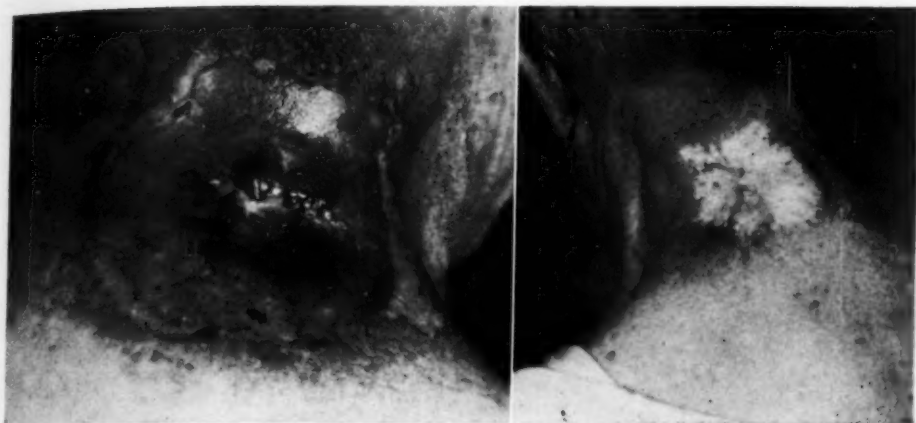
Fig. 7. A. Radiation injury of post-nuchal area five months following interstitial radium treatment for squamous epithelioma at that site. B. Complete epithelialization following five weekly applications of radon ointment.

petrolatum. It is then cooled and is ready for immediate use.

All patients coming to our department with radiation injuries have been treated with radon ointment prepared in this manner. Depending upon the extent of the lesion, from two to ten or more applications are given at weekly intervals. Small circumscribed lesions of brief duration have sometimes been cured after two or three such treatments. For more severe lesions we have had to repeat the treatment over a longer period; in some patients twenty or more treatments have been required before a satisfactory result could be obtained. In no instance have we seen any damage to the patient nor have we encountered any unfavorable reactions. In a few exceptional cases the patients proved to be sensitive to fatty ointment bases and in these instances the application of boric acid ointment had to be replaced by boric acid solution. No other form of therapy was used in conjunction with these treatments.

All patients thus treated showed a favorable response to the application of radon in petroleum jelly, and all whom we could keep under personal observation and continuous control were cured. Since many of our patients came from considerable distances, some difficulty was experienced in following their progress. In most of these instances the radon ointment was shipped

in tin containers and treatment was carried out by local physicians. In some instances this did not work out as well as we had anticipated, either because of faulty technic or because the arrival of the radon ointment was delayed and its strength therefore not as great as originally calculated. Results equally as good as our own were obtained in a United States Army hospital, where the physician who supervised the technical application of the treatment had himself been a victim of x-ray injuries and had been successfully treated three years ago in our department. The majority of patients were more or less completely cured and were well satisfied with the results.

SUMMARY

(1) Radiation injuries to the skin are still encountered in spite of the progress made in radiology.

(2) A great number of the victims are physicians and most of the professionally acquired injuries are due to overexposure in x-ray diagnostic work.

(3) The number of radiologists among the group of physicians is small and in the group observed by us only "old-timers" were affected.

(4) In no instance were injuries to patients produced in diagnostic work by radiologists; those treated by competent
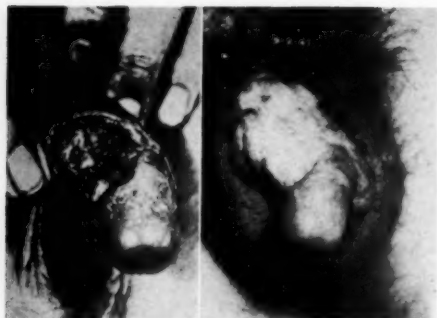
Fig. 8. A. Ulcerating radiodermatitis of the shaft of the penis. B. Complete epithelialization following radon ointment therapy. This patient was treated with radon ointment therapy by his personal physician, the material being forwarded at weekly intervals from our department. (Courtesy of Fitzsimons General Hospital, Denver, Colo.)

radiologists showed relatively minor lesions and most of these followed therapy for malignant tumors.

(5) Alpha radiation applied in ointment form to the injured skin in combination with boric acid ointment has proved of great therapeutic value in the treatment of radiation injuries as shown in some typical examples.

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DISCUSSION

R. R. Newell, M.D. (San Francisco, Calif.): It has been a pleasure to listen to this paper and to have found someone who has a way to cure late roentgen ulcers! I'll admit that to my mind this doesn't make sense and I suspect there are many others who feel the same way. Why chronic ulceration, which everybody knows is "incurable," should be cured by application of the same agent which produced it is beyond my comprehension. Nevertheless, these cases are desperate and I, for one, have a number of patients for whom I would like to try this therapy.

I feel very strongly about these roentgen ulcerations but I am afraid we are talking to the wrong set of people. It is the surgeons who need warning, and the irregular practitioners who need stopping.

I am quite willing to ask the cancer patient to put up with the risk of a late roentgen ulceration when I am trying to save her life. In trying to do other things by radiation, I think we should manage to avoid such a risk.[1]

In certain instances of ulceration I have found urea crystals of some use, but this, of course, is merely palliative and I am anxious now to try the alpha-ray therapy which Dr. Uhlmann has offered us.

[1] At this point Dr. Newell showed some slides illustrating ulceration following overdosage in roentgenography, fluoroscopy, and therapy.

Fluorographic Examination of the Chest as a Routine Hospital Procedure[1]

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IN THE COURSE of the past fifteen years two major factors have been operating to establish photofluorography as an acceptable and useful auxiliary method in roentgenologic examination of the chest. Increasing demand for the mass application of x-ray principles began with the survey of school populations for cases of active tuberculosis, soon spread to industrial plants seeking to avoid the employment of workers already harboring compensable diseases, and has more recently attained gigantic proportions in connection with the wholesale examination of personnel additions to the country's armed forces. Under these favorable growing conditions, schemes by which the costly and somewhat cumbersome procedure of individual roentgen examination of the thorax might be stripped of its practical limitations have developed at a remarkable rate. One of these schemes, the principle of photographing fluoroscopic screen images upon sensitive film of reduced size, has undergone extensive experimental study in the hands of radiologists and the manufacturers of x-ray and photographic equipment until the results which can be thus produced are of sufficiently fine quality to demand the respect and serious consideration of all radiologists. The achieved successes of photofluorography have in considerable measure eclipsed fluoroscopy and the use of paper film as survey procedures, although each of these has its own peculiar advantages as well as its shortcomings.

None except the most ardently partisan exponents of the x-ray survey principle will deny that the most reliable method of employing roentgen methods in any given case is to begin with a fluoroscopic pre-view, followed in all instances by stereoscopic filming, in the erect position, on full-sized transparent film. When indicated, more elaborate procedures, such as supplementary projections in various angles with and without the use of the Potter-Bucky diaphragm, additional fluoroscopy, bronchography, orthodiascopy, kymography, and body-section roentgenography, should be employed. Present-day photofluorographic methods are designed not to supplant these well established procedures, but rather to augment their value by recruiting patients who otherwise might not be subjected to such study. Much of the argument which has been directed against photofluorography and survey methods in general has arisen because this premise was not clearly established in the minds of the debaters. The desirable features of modified roentgen methods applied in mass surveys have appealed strongly to industrial executives, educators, public-health workers, and physicians in fields other than radiology, while its undeniable shortcomings and possible dangers have impressed roentgenologists more forcibly. A meeting of minds dedicated to the rational solution of all problems involved is an imperative step if the control of roentgen diagnosis is to remain in the hands of physicians trained in this field.

One means whereby this can be accomplished is the adaptation of mass x-ray chest survey methods of examination to hospital and clinic practice. The initial scrutiny of routine photofluorograms by the staff radiologist will provide him with an objective means of determining which of all patients presenting themselves for medical service should be referred for searching x-ray examination of the chest. Over and above indications supplied by

the clinical history and initial physical examination he will encounter telltale signs of disease which may easily elude detection by any other method. If, as is true in at least one large American clinic, standard practice already includes stereoscopic filming of all patients upon registration, photofluorography has nothing other than economy to offer—economy at the certain cost of decreased accuracy. If, on the other hand, chest x-ray studies are being made only when clinical suspicions have been aroused, routine photofluorography will broaden the sphere of the staff roentgenologist's usefulness. Experience of this sort will provide radiologists with sorely needed first-hand information regarding the virtues and the weak points of the newer methods. Under their own control the efficacy of patient sifting can be tested and evaluated. Whatever value the method may have will be applied to their own patients, whereas none of the safeguards against diagnostic failure already offered by radiology need be sacrificed.

Once committed to a trial of admission chest survey, the staff radiologist is confronted with the responsibility of deciding which of several available forms of photofluorographic technic he will employ. The decision should not be made lightly nor upon the basis of any single consideration, since each form has certain inherent advantages and disadvantages which are not always immediately apparent.

It is possible at the moment to procure commercially manufactured apparatus of two basic types, the most obvious contrasting feature being the dimensions of the finished film. This is not the only difference, however, for the fluorescent screen supplied with apparatus using 35-mm. strip film is a modification of the well known Type B fluoroscopic screen manufactured by the Patterson Screen Co., whereas the equipment which turns out images on 4 × 5-inch cut film uses a screen of the Fluorazure type. Each has its own peculiarities, which in turn determine the characteristics of the photographic emul-

sion best suited to its use. One may be particularly interested in film cost, in which case it is obvious that 35-mm. stock holds the advantage. If it is desirable that finished films be viewed directly, without magnification of any sort, the 4 × 5-inch size is certainly preferable, if not necessary. Greater diagnostic accuracy in the case of minute tuberculous lesions has been claimed for the larger size (1) and the experiences of Potter and the Herman Kiefer Hospital group in Detroit (2) seem to bear this out, yet it is worthy of note that, whereas the United States Army has adopted 4 × 5-inch film for the examination of draftees and new recruits, the Navy uses 35-mm. equipment exclusively. The ultimate decision should rest in every individual case upon the program which is contemplated, particularly the availability of photographic processing facilities and the subsequent use of films once they have been reported. It is very convenient to preserve films in the order in which patients are examined, which is automatic when strip film is used; but single exposures cut from such strips are difficult to handle and preserve if the program calls for filing with larger films in the patient's record. If the 35-mm. size is chosen, one must decide whether he prefers to view his material by transmitted light and only slightly enlarged, or in larger dimensions by means of projection on an opaque screen. Apparatus needed for 4 × 5-inch films requires a substantially larger initial investment, which may, of course, be the deciding factor. In any event, the selection of equipment is a serious responsibility which demands careful consideration and forethought if any survey project is to achieve its maximum efficiency.

The complexity of equipment problems has been further increased in recent months by the perfection of attachments for the incorporation of stereoscopy, now available for use with film of either size. The great advantages of three-dimensional vision, long appreciated and practically employed by radiologists, are fully apparent in photofluorography. These advantages are off-

set somewhat perhaps by added equipment and film costs, as well as by some loss of storage space economies, but in the long run these considerations are certainly unimportant. It is doubtful if any radiologist who has once viewed miniature films of the same chest obtained with and without the use of stereoscopic apparatus will ever again be entirely satisfied with single projections. Film quality is further enhanced by the use of a stationary, focused wafer grid, the lines of which are so fine as to be entirely invisible under normal reading conditions. Almost indispensable in the case of obese patients, the grid adds materially to the brilliance of all chest films. Whatever one may choose in the way of photofluorographic apparatus, it seems certain that early obsolescence is to be expected, so rapid is the rate at which this new technic is being developed.

In order to serve its fullest purpose as a screening device for all intrathoracic abnormalities occurring in the patient population, miniature chest filming should apply to every person registered in the hospital or clinic, at the time of initial contact, and the results of this preliminary examination should be made available to the medical staff with the minimum of delay. Ideally the chest-filming station should be incorporated in the quarters devoted to the registration and admission of patients. Not uncommonly this will be at a point far removed from the central x-ray division, necessitating the establishment of an outlying activity to be administered and operated by the roentgenology staff. Since high energies are required to produce photofluorograms as compared with conventional roentgenograms, suitable high-capacity power supply must be provided unless a generator of the condenser-discharge type is employed. Twenty-four-hour service must be provided to accommodate admissions at odd hours unless patients so registered are to be excluded from the survey or provision is made for their examination on the following day. It is not enough that findings be posted in each patient's record. For future access to accumulated clinical material, consolidated findings of each day's work must be prepared. This entails provision for clerical activities, which must be rapid, punctual, and accurate. Completed films must be filed in accessible form to facilitate direct comparison with conventional roentgenograms subsequently obtained. The entire success of routine chest survey in an active hospital or clinic depends upon smoothly efficient and dependable operation of the venture, and this in turn rests upon thoughtful planning and the whole-hearted co-operation of all persons concerned.

On the basis of a conviction that measurably increased accuracy and speed of diagnosis would result from its operation, several staff members, representing various clinical departments at the University of Michigan, have for some years urged the institution of a preliminary x-ray chest survey service applicable to all patients registering at the hospital and clinic. During the past seven years routine chest filming of all newly entering University students has amply proved its worth as a means of detecting unsuspected pulmonary disease, and applied to hospital employees in all categories, the procedure has become a firmly established custom. During a two weeks' period in 1935 the plan was applied on a trial basis to all registering patients in the admitting division of the hospital. As a result of this experiment the medical value, as well as the entire feasibility of the venture, was established to the satisfaction of all concerned (3). The initial cost of equipment installation, including necessary building alterations, was the only deterrent to permanent adoption. Ultimately, in April 1939, the necessary funds were provided through the generosity of the W. K. Kellogg Foundation in response to the University's request. By this time successful steps in the development of photofluorographic technic seemed to warrant the substitution of the procedure for the more nearly standard practice of using single 14 × 17-inch films, thereby simplifying the financing of daily operation.

The problem of deciding upon the type of apparatus to be installed settled itself automatically, for all available lenses of the sort necessary to the production of 4 × 5-inch miniatures were commandeered by the Army. Prompt delivery of 35-mm. equipment then in process of commercial development could not be guaranteed, and the only course open was to seek the aid of the department of physics in building the accessory parts necessary to adapt a miniature camera of standard make, fitted with an f. 1.5 lens, to the needs of chest photofluorography. The totally unexpected and variegated difficulties encountered in designing, building, and operating this homemade apparatus are of no importance in the present discussion, since it is now possible to select commercially built equipment which can be supplied without delay. It is pertinent, however, to consider equally significant difficulties arising in connection with the establishment of admission chest filming as a routine procedure, for these are not automatically overcome with the completion of equipment installation.

The inclusion of every newly registered patient is highly desirable if the maximum benefits of routine survey are to be realized. Simple as it at first seems to accomplish complete coverage, many factors were found to operate against this aim. Patients in critical condition upon entry are obviously in no condition to be subjected to the registration routine and are at once transferred to bed. Some patients are admitted under emergency conditions after regular clinic hours and thus escape the x-ray filter, at least for the moment. The private patients of individual staff members are often registered by proxy and may be sent down for admission filming one or two days after the registration date, a practice which often leads to confusion. To make provision for these irregularities entails additional technical services, which add expense out of proportion to the number of patients involved. Arbitrarily only those patients who appear in person in the admitting division during regular clinic hours are included unless the staff member involved takes the initiative in correcting the omission.

The apparatus, together with photographic processing facilities, is housed in direct connection with the admitting service, remote from the central x-ray laboratory. A full-time technician of long experience in chest roentgenography is easily able to position and film all patients. The necessary speed of handling is variable, having reached a maximum, in our experience, of one hundred per hour. Film processing is carried out by a part-time dark-room technician who devotes a daily average of two hours to this work. Since our equipment requires that film be used in 36 exposure daylight-loading rolls, the meticulous technic of processing has not been mastered without great effort and numerous discouraging errors. The selection of photographic emulsion and the developer best suited to its characteristics did not prove to be a simple matter.

It is axiomatic that the results of survey filming should be made available with minimum delay. Allowing ample time for processing and interpretation, as well as the clerical steps which are inescapable, it is not feasible to adopt a daily schedule which calls for a time lapse of less than three hours. Although the grist of miniature films for any day can be interpreted without difficulty in twenty minutes, it would become an irksome duty if it were necessary to schedule several such reading periods each day in addition to regular responsibilities in diagnostic roentgenology. Many factors must be taken into consideration in establishing the time boundaries of the daily report period. At the University Hospital, patient registration is active during the forenoon, slack in the afternoon. Most patients appear for registration during the first three days of the week. In view of this situation, the films of patients registered during the twenty-four-hour period between twelve noon and twelve noon are interpreted at 2:00 P.M. Immediately thereafter reports in the cases where findings of obvious or suspicious clinical

significance have been discovered are rushed to the division in which the patient was registered. Reports for the entire period are consolidated, in order of registration number, in three classes according to observed findings, and, reproduced with a ditto machine, are sent to each clinical division, arriving at the beginning of the

it is by no means ideal, is thoroughly workable in practice.

To implement the reporting procedure, special blank forms have been prepared which carry in ballot form thirteen standardized findings which can be scored with check marks (Fig. 1). A fourteenth unspecified finding is left blank to provide for

Fig. 1. Form used for report of admission chest roentgenogram. The explanation of the report appears on the reverse side of the form.

following day. In the meantime, individual reports are dispatched by vacuum tube to catch up with the remainder of the patient's clinical record. Entirely negative and clinically insignificant findings are reported in the consolidated report by clinic number only, whereas findings which in the opinion of the examiner warrant further, more searching x-ray examination are identified by number, name, and service to which admitted. This plan, while

unusual observations which are to be written in by the examiner. The blank also carries voting space for the examiner's impression to be expressed by designating into which of three classifications the miniature photofluorogram falls: "A," when no abnormalities are observed; "B," when deviations from normal do not appear to be clinically significant; "C," when changes, observed or suspected, convince the examiner that more thorough roent-

TABLE I: PATIENT VOLUME AND CLASSIFICATION

	"A"	"B"	"C"	Unsatisfactory (No report)	Total Examinations
July	1,387	248	163	59	1,857
August	1,449	270	178	31	1,928
September	1,495	341	204	62	2,102
October	1,471	245	187	51	1,954
	5,802	1,104	732	203	7,841
	74%	14.1%	9.3%	2.6%	100%

genological examination of the chest is highly desirable. The blank carries a detachable coupon, upon which duplicate entries are made, which is retained in the x-ray department. Upon the coupon the examiner indicates the extent and specific type of roentgen examination which he feels should be carried out, and when the patient appears for the examination recommended, this information is readily available. Stamped with pertinent regis-

tion. Abnormalities thought to be of no immediate significance, such as lime salt deposits in lung, lymph nodes, and pleura, were observed and recorded under group "B" in 1104 or 14.1 per cent, while in 732 patients, 9.3 per cent of the entire group, class "C" was used to indicate the advisability of more extensive roentgenologic study. In the case of 203 patients, 2.6 per cent, films were technically unsatisfactory (Table I). As a result of the test experi-

TABLE II: DISTRIBUTION OF SCORED FINDINGS

204 Group "C" Patients, September 1941

Rib anomaly	0	Calcified scar, lung	24
Lung anomaly	1	Abnormal aorta	13
Acquired bone lesion	7	Abnormal heart	43
Pleural scarring	21	Mediastinal mass	21
Pleural effusion	5	Pulmonary lesion	98
Pleural calcification	2	Pulmonary lesion (?)	42
Calcified nodes	18	Other than above	34

tration information, blank and coupon alike are issued to the patient in the admitting division. The actual date of routine filming, not always identical with the registration date, is added to blank and coupon by the technician at the time of examination.

Begun July 1, 1941, at the University Hospital, photofluorographic examination of patients at the time of registration has been conducted daily with the exception of two days when tube failure, scarcely chargeable to the new procedure, forced interruption of the routine. Many of the patients affected by the shut-down were subsequently examined. During the first four months of operation 7,841 patients were examined. Of the total, 5,802 or 74 per cent were found to have no abnormalities detectable by this method and were accordingly placed in the "A" classifica-

ment in 1935, distribution among the three classifications was somewhat different: "A" 68.3 per cent, "B" 23.6 per cent, and "C" 8.1 per cent. The fact that a higher percentage of patients are being remanded for further examination as the result of the present photofluorographic survey is probably best explained by the newness of the method and the examiner's efforts to avoid errors of omission by placing in the "C" group every patient whose film even vaguely suggests the presence of a pulmonary lesion.

In the month of September, thoroughgoing roentgen examination was recommended on the basis of survey findings in the case of 204 patients. Specific findings scored in this group are listed in Table II. For a variety of reasons recommended re-examination was not carried out in the case of 71 patients. In some cases the ab-

normality found was already known to exist, as shown in available roentgenograms prepared elsewhere or in our own files dating back to a previous admission. In others the patient had come to the clinic as an outpatient and had departed before the results of survey examination were available. In still others the patient elected to forego further examination or to have it conducted elsewhere. One hundred and thirty-three patients, or 65 per cent, were re-examined as suggested. Within this group "pulmonary lesion," reported 69 times, was confirmed in 51, disproved in 5, while some situation other than a lesion of the lung itself was discovered as the cause of the finding in 13. In this same group, classified as "C" during September and subsequently subjected to standard x-ray chest examination, "questionable pulmonary lesion" was reported 25 times. The suspicion of pulmonary lesion was confirmed in 13, disproved in 10, while some other explanation was offered in 2. It is noteworthy that although the suspicion of pulmonary disease was unwarranted in several instances, the miniature film had justified its use by pointing to the advisability of further study, even though it could not provide grounds for final diagnosis. Corresponding results of follow-up examination in the case of patients who were scored as showing aortic, cardiac, and mediastinal lesions, as well as those with signs of abnormalities not covered in the formalized listing, are shown in Table III.

TABLE III: SUBSEQUENT CONTROL
94 Group "C" Patients, September 1941

Survey report: pulmonary lesion 69
  Confirmed 51
  Other lesion 13
  Disproved 5
Survey report: questionable pulmonary lesion . . . 25
  Confirmed 13
  Other lesion 2
  Disproved 10

Errors of omission are detected with more difficulty since, in addition to the factors which interfere with follow-up examination when this is specifically urged, the survey report, when it states that no abnormality has been found, may deter the physician in direct charge of the patient from seeking further roentgenologic assistance. Results of the few re-examinations conducted among group "A" patients surveyed in September are shown in Table IV.

TABLE IV: RE-EXAMINATIONS OF GROUP "A" PATIENTS
SURVEYED IN SEPTEMBER (15 DAYS)

Total survey films	664
Stereoscopic chest examination in x-ray department	66
Reclassified as B or C	16

300255.   Minimal rib anomaly, anterior portion third rib, right
488832.   Azygos lobe
489153.   Calcified hilar adenopathy, left
489048.   Calcification, left hilum
488914.   Calcified tuberculous scarring, left lung and hilum
434124.   Calcified tuberculous scarring, left upper lobe
488945.   Tortuous, elongated aorta
488429.   Elongation and tortuosity of thoracic aorta
466352.   Calcified parenchymal and hilar scars; uncalcified parenchymal scars
459831.   Minimal tuberculous scarring, left apex
292997.   Minimal tuberculous lesion, left apex
488617.   Interstitial pneumonitis, left lower lung field
335303.   Chronic pneumonitis, median inferior portion each lung
488924.   Area of consolidation, right lower lobe (age, 10 months)
489036.   Granular appearance of each lung, compatible with mild pneumoconiosis
489058.   Advanced pulmonary emphysema

It is of the greatest importance that the true purpose of wholesale survey efforts be carefully explained to all concerned and that the well established indications for specialized types of x-ray diagnostic service be heeded irrespective of survey findings. The survey plan is not infallible in tracking down obscure intrathoracic disease; it is idle to assume that a procedure so simply and so rapidly employed can adequately supplant all accepted methods of roentgenologic examination, as well as careful history-taking and methodical physical examination. Chest survey is designed to assist in the establishment of final diagnoses and, in common with all fact-finding agencies employed in medical practice, it has its limitations. Intelligently used as a screen set up to detect at the outset objective indications for more elaborate roentgenologic scrutiny of the

thorax, the photofluorographic survey of entire hospital populations is perhaps most effective in identifying advanced, open cases of pulmonary tuberculosis capable of transmitting the disease to other patients and to hospital personnel unless rigidly isolated. One such patient, whose medical history misled the internist who first saw her to believe that her symptoms were caused by bronchiectasis, was promptly discovered to have widespread tuberculosis with extensive cavitation, referred for confirmatory x-ray examination, which in this case was scarcely necessary, and sent off to the state sanitarium before she could threaten the health of those about her.

Most of the arguments used against photofluorography are centered about the inability of these methods to furnish tangible evidence of extremely early tuberculous lesions with the accuracy which has been established for large film stereoscopy. To condemn the method on this score is to overlook the fact that it can and will be applied in medical practice far more frequently than standard procedures and that by virtue of its wider use, it will call attention to the need for searching x-ray investigation in many instances where this need is not otherwise apparent. Its position as a routine step in the registration of patients is clearly analogous to routine examination of the urine and routine serologic testing for syphilis. It is unthinkable that final medical opinions will be based upon such initial laboratory tests when there is any reason whatever to suspect that more exhaustive investigation by the same personnel in the same laboratories may yield additional information of value. Approaching the subject of chest survey for hospital patients from the same point of view, there is no reason to doubt the wisdom of adopting this plan. In our experience positive serologic reactions are found in slightly more than 2 per cent of all patients examined, whereas the chest survey uncovers evidence of significant disease in four times that number. The cost of providing routine laboratory service is absorbed by the establishment of a registration fee which if slightly increased can easily meet the cost of chest survey.

Thus far at the University Hospital stereoscopy and the wafer grid have not been available for the photofluorographic project. Unquestionably these technical features make for better visibility of intrathoracic structures and are therefore clearly to be desired. Whether this innovation in roentgen diagnosis will sometime make inroads into the other fields where roentgen methods at the present reign supreme may well be left for the future to decide. Its worth as a survey instrument restricted to the business of sorting out persons with obvious chest disease from among large population groups, while not absolute, compares very favorably with other thoroughly accepted diagnostic measures.

CONCLUSIONS

1. Even with homemade apparatus which includes neither provisions for stereoscopy nor a stationary grid for the elimination of excessive scattered radiation, photofluorography employed to survey the chests of all patients regularly registered in hospitals and clinics can be expected to disclose signs of significant thoracic disease in 8 to 10 per cent of the patient group. Technical improvements already available will increase its accuracy and usefulness.

2. Chest survey of all hospital and clinic patients will yield more positive findings than serologic testing for syphilis similarly applied.

3. Detection of the minute early lesions of pulmonary tuberculosis is neither the sole nor even the prime purpose of admission chest survey when employed in general hospital practice. Under these circumstances the discovery of unsuspected chest lesions of larger magnitude is of greater practical value.

4. If carefully planned and directed, routine chest surveys in general hospitals can be made workable and effective without overloading or hampering the department of roentgenology. Chest diagnosis

within the department becomes more interesting and more valuable.

5. Photofluorography offers a means of supplying a valuable form of x-ray service when considerations of cost, time, and labor render conventional stereoscopic chest examination impracticable for all patients admitted.

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DISCUSSION

Warren W. Furey, M. D. (Chicago, Ill.): In reference to Dr. Hodges' presentation I can only add what Dr. Hollis Potter has said, that survey consciousness is upon us and whether the survey is done on large or small groups, whether it is done with large or small films, makes little difference. It is the result that counts. Doctor Hodges' results speak for themselves. They compare favorably with those coming from other sources regardless of the method used.

One point I should like to add: survey work will undoubtedly eventually become a rather generalized procedure and when it does our chief concern should be that, so far as possible, it be kept under the control of radiologists. Doctor Hodges has suggested one excellent way for us to prevent outside control.

Mass Roentgenography of the Chest
for the United States Army[1]

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ROENTGENOGRAPHY is generally recognized today as a most trustworthy procedure for survey examinations of the chest. This evaluation is quite in contrast to the practices of five to ten years ago and those at the time of our last great mobilization, for World War I. Because of the less adequate examinations which prevailed during those times, some unfortunate

there was no reason to expect recognition by the ordinary procedures of physical examination, but which broke down under the stress of military life. Individuals of these two groups were probably responsible for some dissemination of the disease, through "buddy" contacts. Even though these three sources be considered, however, and though other sources of contact in-
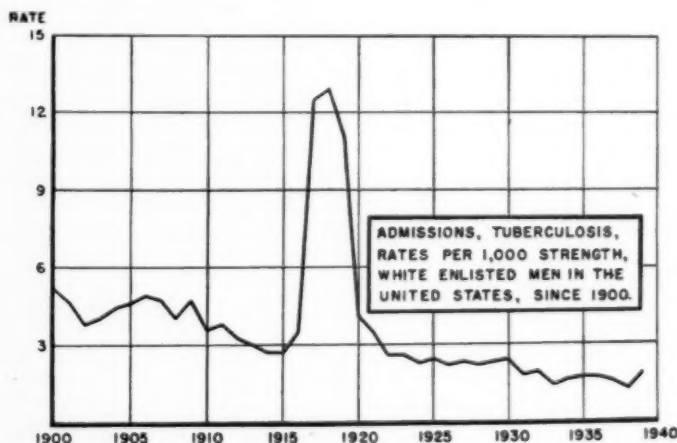

Fig. 1.

consequences resulted. Statistics of the Surgeon General's office indicated a sudden increase in hospitalizations during the years 1917–19, due to conditions which were considered as "pulmonary tuberculosis" (Fig. 1).

Some of these admissions, no doubt, were due to activity of actual tuberculosis. Minimal lesions might easily have escaped recognition and the bearers have been accepted for the Service. Likely, there were cases of dormant infection for which

fection be added, it is difficult for epidemiologists to account for the entire increase in the hospital admission rate on such bases. Many cases were probably erroneously classified as "pulmonary tuberculosis" (1).

The patriotic spirit of the American people has been such as to allow every benefit of doubt in favor of the individual concerned, and since no preliminary graphic records were available for comparison when claims for compensation were made, there resulted an enormous expenditure of federal funds for pensions and compensation of one sort or another (2, 3).

This background indicates several rea-

sons for obtaining more complete examinations in the present mobilization. There must be obviated, first of all, any unnecessary dissemination of diseases such as pulmonary tuberculosis. The hospitalization rates (soldier-days-lost) must be reduced as compared with the last great mobilization. Finally, and equally important to our country as a whole, the Government must be protected against false claims due to lesions not associated with the Service. This latter aspect does not imply that just compensation will not be recognized for actual service-connected lesions. In short, these experiences have enforced a policy of examination which should serve both epidemiological and legal purposes.

AVAILABLE METHODS

Approximately two years ago the question was presented as to what roentgenographic procedure would most satisfactorily answer the two-fold requirement mentioned above. It was realized that each of several methods then available must be studied and evaluated in terms of the particular needs. The problem involved more than an evaluation of the various methods with respect to diagnostic trust which might pertain to the study of one or a few cases. It could be expected that several hundred examinations would have to be carried out each day. The roentgenologist would have to co-ordinate his services, in a very timely manner, with those of other examiners. Thus, the aspects of optical and mental fatigue had to be considered, as well as speed in accomplishing the examinations. Furthermore, it was anticipated that the records might be reviewed later by other authorities and that for such purposes they might have to be shipped to one and another location. This required a rating as to the practicality of transferring substantial evidence; it involved the considerations of durability of the records and ease of handling. Comparative costs were considered, too, particularly the unit cost per examination, though it was realized that even the most expensive procedure would be money-saving.[2] The costs for auxiliary equipment also entered into the matter, though it was realized that, allowing for studies prior to admission and again before discharge, so many examinations were concerned (approximately 8,000,000 as far as our immediate program is concerned) that such costs would relatively be cancelled. At that time it was also necessary that we consider the matter of availability of equipment, but this aspect no longer constitutes a problem. Table I, on the following page, is presented to portray our several evaluations with respect to the various roentgenographic procedures.

Trust for Single Case Study: It will be noted that with consideration of the single case study, stereoscopic 14 × 17-inch conventional films were preferred; that next to them, preference was given stereoscopic 4 × 5-inch films, miniature films of these dimensions, when provided for stereoscopy, being considered preferable to a single 14 × 17-inch film. It will also be noted that a stereoscopic 35-mm. film study was preferred to a single 4 × 5-inch film study. These ratings emphasize our attitude toward stereoscopy. Its value is widely recognized. It affords easy viewing, with less visual and mental fatigue (provided

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[2] It is estimated that "about one per cent of the male population of military age has active tuberculosis, most of which can be detected only by x-ray examination" (4, 5). It is practically impossible to develop an estimate as to the average cost of cases which have received compensation, in one form or another, from our Government, since so many of the men are still living. The following figures, however, may indicate the high expenditure on this account (6). For 51 persons still living, selected at random among those who requested benefits in 1919, the average individual cost to date is $15,531. This includes the following averages for each: compensation, $12,957; vocational training (received by 24 of the 51), averaging $2,394 per case; hospitalization (received by 20), averaging $2,347; insurance (received by 6), averaging $4,481. It must be emphasized that all of these 51 men are still living and that each is still receiving $50.00 per month. Forty-nine of them are listed as "arrested" cases; two of them as "active."

For 13 men whose benefits began in 1919 and who have died, the average cost was $14,131. Five of these obtained a disability compensation which averaged $5,099; 2 had vocational training averaging $1,360; 3 hospital care, the cost of which averaged $2,060, and in 10 cases insurance was given to the individual or to his dependents, with an average cost of $10,917, while in 7 of the cases dependents were paid an average of $5,734.

true stereoscopic projections[3] are accomplished), but, more than that, it provides for (1) the separation of parenchymal densities from overlying soft tissue densities and from osseous densities such as are referable to the ribs and spine, (2) the distinguishing of peribronchial irregularities which may be due to involuntary movements of the pulmonary vessels or to actual changes in the lymphatics or fibrous tissues, and (3) control against defective artefacts, which may occur either because of transient changes in radiographic performance or improper handling of the film.

studied by third-dimensional viewing though that, too, is favored.

Provisions for stereoscopy of miniature films were not available to a practical degree when our program was being formulated. Stereoscopic viewing apparatus had not been constructed for these films. Cut films were used at first, and projected with the use of a standard Wheatstone type of stereoscope. It became evident that third-dimensional viewing contributed even more in the case of the miniature films, as compared to flat film viewing, than in the case of the conventional large films.

TABLE I: COMPARISON OF METHODS OF CONDUCTING LARGE-SCALE ROENTGEN
STUDIES OF THE CHEST

METHOD	TRUST FOR SINGLE CASE STUDY	TRUST FOR MASS STUDIES	COORDINATION WITH OTHER EXAMINATIONS	FUTURE REFERENCE	UNIT COST * PER EXAMINATION	INITIAL COST OF AUXILIARY EQUIPMENT
X-RAY FILM 14 X 17 STEREO	1	3	7	3	$1.08	CANCELLED
X-RAY FILM 14 X 17 SINGLE	3	6	6	3	54¢	CANCELLED
X-RAY PAPER 2 EXPOSURES	3	7	7	4	68¢	CANCELLED
X-RAY PAPER SINGLE	4	8	6	4	34¢	CANCELLED
FILM 4 X 5 STEREO	2	1	5	1	10 – 12¢	$2600
FILM 4 X 5 SINGLE	6	4	3	1	6 – 8¢	$2200
FILM 35 MM STEREO	5	2	4	1	1½ – 3¢	$2000
FILM 35 MM SINGLE	7	5	2	2	1 – 2¢	$1400
FLUOROSCOPY	8	9	1	NONE	NEGLIGIBLE	CANCELLED

AS OF APRIL 1, 1941
* ESTIMATED ON THE BASIS OF AVERAGE DISCOUNTS PLUS ALLOWANCE FOR CHEMICALS

These attributes of stereoscopy are particularly important when hundreds of cases must be studied in a day and when the films may serve for legal evidence. Certainly, a two-film record showing duplication of evidence should be irrefutable. It is merely important that the second projection be made after shifting of the x-ray tube, whereby the incident x-ray beam is changed from one point source to another. It is not mandatory that these images be

It was realized, too, that where great numbers of cases must be studied within minimal time limits, equipment must be provided for accommodating the pair of images on an uncut film (*i.e.*, the two images being attached). This requirement was explained to the manufacturers with the result that today three concerns are providing film shifters and special stereoscopic viewing units

Trust for Mass Studies: Considering this basis of evaluation (column 2, Table I), it will be noted that when mass x-ray studies are to be conducted, stereoscopic viewing of the 4 × 5-inch films is given priority, and stereoscopic studies with the 35-mm. films are also highly rated. There

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[3] Not infrequently, the film images are improperly positioned with respect to the "right-eye image" *versus* the "left-eye image." Particularly when using a two-image film (*i.e.*, not cut films) it is important that the direction of the x-ray tube shift be co-ordinated in relation to the direction of the film shift and to the design of the viewing apparatus (*i.e.*, whether mirror type or prism type).

are several reasons for this. The factor of fatigue must be considered. For those who have become accustomed to third-dimensional viewing, *true* stereoscopic viewing is less fatiguing than flat film viewing. Miniature stereoscopic viewing is particularly appreciated because, with the smaller dimensions, the scope of the field is within that of visual concentration. In this respect, detailed viewing of a standard 14 × 17-inch film has appeared to be comparable to studying at least four, and possibly six, of the miniatures. In short, at least as far as searching for abnormalities is concerned, the time requirement for study of the miniatures is reduced from that required for the large film images.

Co-ordination with Other Examinations: The matter of expediting the examination is likewise of considerable importance. It was planned that the x-ray study be accomplished as the first procedure in the general examinations. One of the last phases of the examination would be the physical examination of the chest. By the time the candidate might reach the latter examiner, the report of the roentgenologist, as well as the film records, should be available, thereby providing for concerted physical studies as indicated. For such co-ordination it was necessary to consider the ease and speed of processing one or another type of film and other records. For instance, it would be expected that a roll type of film or a two-image film would be handled more rapidly than individually cut films. Likewise, any requirements as to special handling were taken into consideration. These aspects governed the evaluation listed in column 3 of Table I.

Practicality of Reference: The legal aspects compelled planning as to storage and consideration of the durability of the records. The storage problem was no insignificant one. If 14 × 17-inch standard films were to be made and two such allowed for each examination (prior to admission and again prior to discharge), it would require a cabinet space equivalent to no less than 20,000 standard cabinet drawers to accommodate them, segregated in enve-

lopes. If placed back to back the films would extend for approximately eight miles, while their weight would be no less than 800 tons. Slightly greater space requirements and similar weights pertained to the 14 × 17-inch paper films. The miniature films reduce these requirements from 1/6 (in the case of the 4 × 5-inch films) to approximately 1/150 (in the case of the 35-mm. films).

The matter of durability also required thought. In case of pension claims there might be reason to study the films twenty or thirty years after their first being reported. Inadequate fixation of the emulsion, incomplete washing for the removal of all sulphides, or unsatisfactory storage conditions would no doubt result in yellowish staining or even fragmentation of the films. They might be called for at frequent intervals and, unless they were very sturdy, the handlings in cataloguing and shipping could be expected to render them entirely useless. Very small cut films are likely to be lost—hence the slightly lesser rating given the single 35-mm. type.

Unit Costs: The tabulation of unit costs would seem to be self-explanatory. The values listed are basic costs, including merely the cost of the film and allowances for chemicals. They do not include allowances for rentals nor salaries of personnel, thus differing from certain estimates published elsewhere.

Initial Costs: The consideration of initial costs was limited to auxiliary equipment, since it was reasoned that the generator equipment was a requirement common to any roentgenographic procedure and as such would be needed for other studies. It is true that x-ray tube consumption can be expected to be greater with photoroentgenographic adaptations than for conventional chest roentgenography and, as far as the miniatures are concerned, that greater punishment and therefore shorter tube life can be expected with 4 × 5-inch film work.

OFFICIAL PROCEDURE

This analysis prompted adoption of the 4 × 5-inch photograph of the fluoroscopic

image. It was decided, as a routine, to accomplish stereoscopic projections of this dimension, though it was realized that in doubtful cases standard 14 × 17-inch conventional films might be needed and they, too, were authorized. Where equipment for the 4 × 5-inch film work is not available, standard 14 × 17-inch films or paper films are routinely used, at least temporarily.

It would not seem practical to discuss here generalities concerned in this procedure. The construction features of the equipment, the character of the fluoroscopic screen, and other details have been described in current literature (7–14).

SPECIAL TECHNICAL FEATURES

There are certain technical features which do not seem to be applied, generally, and which appear to be particularly valuable when large numbers of examinations must be conducted within minimum limits of time. These include such considerations as the most practical milliamperage, the requirements as to capacity of the x-ray tube, type of film to be used, exposure factors, counteracting secondary fog, and details as to focal-fluoroscopic screen distance.

Milliamperage: It is believed that the most practical milliamperage, at the present time, is 200. This calls for an x-ray generating unit having full-wave rectification and a load capacity of no less than 200 ma. at potentials as great as 100 kv.p.

X-Ray Tube Requirements: When studying great numbers of men as rapidly as is required for Army purposes—200 to 400 a day—it is necessary to make exposures at the rate of one to two per minute. This requirement imposes severe punishment upon the x-ray tube. This punishment may be estimated in terms of "heat units"—kilovoltage times milliamperage times time in seconds. X-ray tubes withstand such punishment according to three characteristics in their construction: (1) heat-loading capacity, (2) heat-storage capacity, and (3) heat-dissipation rates. With stationary anode tubes a relatively large focal spot is required to withstand 200 milliampere im-

pacts, as recommended above. This refers to the heat-loading capacity. The heat-storage capacity and heat-dissipation rates govern the "heat unit capacity per hour." For our work it is deemed practical to provide for no less than 700,000 heat units per hour. This is the main reason for our having to use stationary anode tubes (*i.e.,* rather than rotating anode tubes). With such, there is required a focal spot approximately 5 mm. square (as projected). The shortcomings of the large focal spot are compensated to a considerable extent by the reduction factor of the lens (used in photographing the fluoroscopic image).

Single Emulsion Films: Ordinarily, conventional x-ray films have been used for the 4 × 5-inch photographing of the fluoroscopic image. The conventional x-ray film is duplitized; it has a coating of emulsion on both sides of the base. This film was tested as to the intensity of the image produced upon the second emulsion and the character of the image produced on each of the emulsion coatings. It was found that a considerable percentage of the fluorescent rays actually do penetrate the first layer of emulsion and the supporting base of the film, to become effective upon the emulsion which is coated upon the back of the base. Moreover, it was found that the light rays are reflected and refracted before reaching the second emulsion coating, with the result that the second image shows conspicuous unsharpness in detail. Thus, with a duplitized film, a blurred image (of the second emulsion) is superimposed upon a sharper image (of the first layer of emulsion). The combination is an image which, for the miniature dimensions, is too greatly lacking in detail.

Duplitization enhances the contrast characteristics of the image. Reproduction of an image which inherently possesses high contrast characteristics, however (such as pertain to a fluoroscopic image), is likely to result in too great a degree of contrast. The blacks and whites become too extreme in degree with too short a scale in gradation of the densities. There appears to be rea-
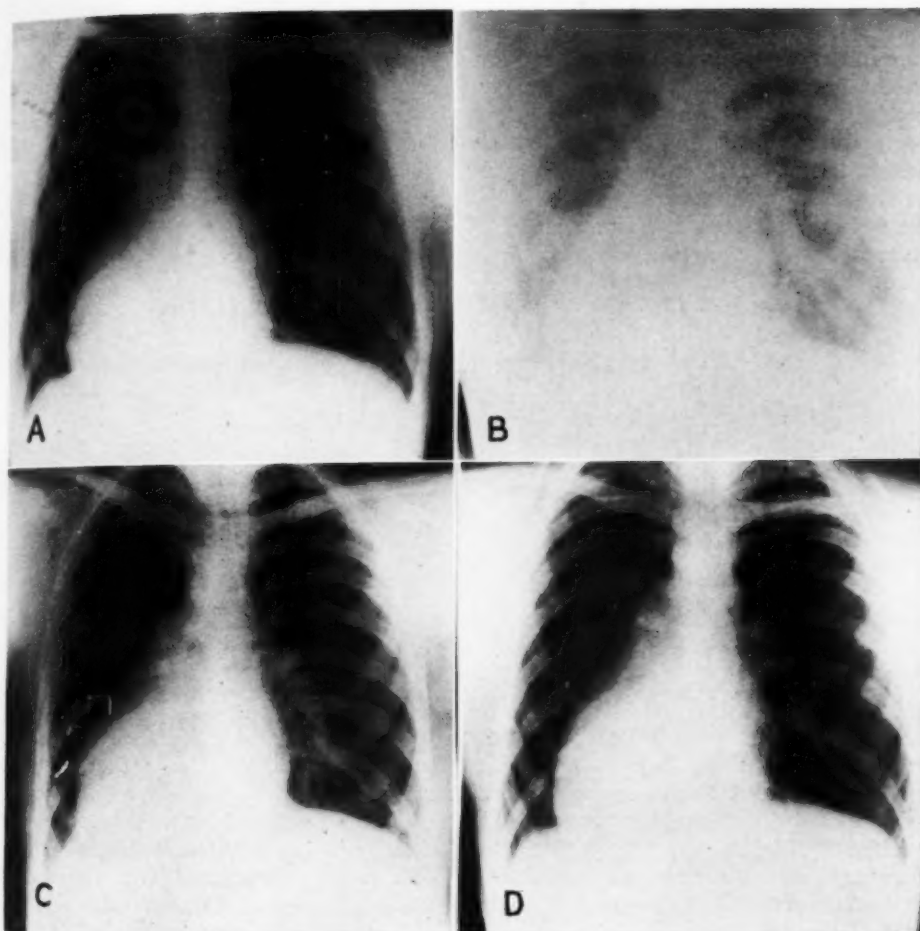
Fig. 2. Analysis of densities and detail obtainable with a single coating *versus* two coatings of emulsion.
A. Radiographic effect upon front coating of duplitized film (front image).
B. Equivalent effect upon second coating of duplitized film (rear image).
C. Combined radiographic effect with duplitized film (double image).
D. Radiographic effect with single emulsion film.
Note the considerable effect upon the second coating of the duplitized film and the unsharpness of detail of its image; therefore, the lessened sharpness of detail with the combined coatings as compared with the single coating, A, or the new film, D.

son to counteract a build-up of contrast, and in this respect, too, single emulsion films appear to be indicated. Thanks to the co-operation of a film manufacturer[4] a special single emulsion film has been developed which permits handling and processing as with standard x-ray films.

High Kilovoltage Technic: Excessive contrast might also be counteracted by the use of high kilovoltage. The usual kilovoltage range utilized for roentgenography of the chest is between 60 and 70 kv.p. For photography of the fluoroscopic image it is practical to use kilovoltages of 80 to 90 kv. p. (or up to 100 kv.p., if the equipment can tolerate these latter values). These higher kilovoltages provide for pro-

portionate decreases in the exposure time, thereby reducing the likelihood of unfavorable effects of motion. They also provide for greater uniformity of radiographic results. Moreover, heat unit requirements are reduced with high kilovoltages in comparison with low kilovoltages—and thereby the tube is actually spared. This fact is exemplified by the comparisons of technical factors shown in Table II.

as a moving grid (*i.e.*, a true Potter-Bucky diaphragm). A stationary grid (*i.e.*, wafer grid) is satisfactory. Because of the reduction factor of the lens of the photoroentgenographic camera unit, grid marks are not conspicuous, nor, indeed, are they visible without magnification when projected from these non-moving grids, provided the lead lines are so thin that as many as fifty can be accommodated to the inch

TABLE II: COMPARISON AS TO PUNISHMENT IMPOSED UPON X-RAY TUBES IN TERMS OF HEAT UNITS WITH LOW AS COMPARED TO HIGH KILOVOLTAGE

| | LOW KILOVOLTAGE TECHNIQUE | | | HIGH KILOVOLTAGE TECHNIQUE | | |
| | (USING 200 MILLIAMPERES) | | | | | |
CMS. THICKNESS	KV. P.	TIME IN SECS.	HEAT UNITS	K.V.P.	TIME IN SECS.	HEAT UNITS
16	57	1/5	2280	72	1/10	1440
17	59	1/5	2360	74	1/10	1480
18	61	1/5	2440	76	1/10	1520
19	63	1/5	2520	78	1/10	1560
20	65	1/5	2600	80	1/10	1600
21	67	1/5	2680	82	1/10	1640
22	69	1/5	2760	84	1/10	1680
23	71	1/5	2840	86	1/10	1720
24	73	1/5	2920	88	1/10	1760
25	69	1/4	3350	90	1/10	1800
26	71	1/4	3550	90	1/10	1800
27	73	1/4	3650	90	3/20	2700
28	75	1/4	3750	90	3/20	2700

Secondary Fog: The usual indications for considering secondary radiation are great density and thickness of the part. Because of the aeration and therefore low density of lung tissue, the problems of secondary radiation are not ordinarily associated with roentgenography of the chest. Some fogging of the films due to this cause may occur in the case of very thick chests, or with the use of x-rays of relatively short wavelength, as produced with the higher kilovoltages. The inherent fog and the susceptibilities to fogging vary depending upon emulsion characteristics as well as upon the developer. With most emulsions it is practical to use a grid (*i.e.*, Bucky diaphragm) with kilovoltages of 85 or higher, though it must be realized that the "critical" kilovoltage value depends upon at least three other factors: density of the part, its thickness, and the characteristics of the film.

When applied to the procedure of photographing the fluoroscopic image, the grid need not be of so complicated construction

width of the grid. Such a grid has been made for the Army.[5] Even though the grid ratio be relatively low (*i.e.*, 5 to 1 *versus* the conventional 8 to 1 recommended for chest roentgenography), definite improvement of film quality is obtained for the higher kilovoltage values which are recommended, as compared with the results of non-grid technic. Because of the stationary feature of the grid, the exposure time need only be doubled, rather than tripled or even further increased, as is usually required with moving grids.

Focal-Fluoroscopic Screen Distance: Considering the light transmission characteristics of lenses available for the 4×5-inch film today, a focal-fluoroscopic screen distance of 36 to 48 inches is believed practical. If the distance be reduced to less than 36 inches, there results a conspicuous degree of distortion. The image is then of dimensions so great that even an average
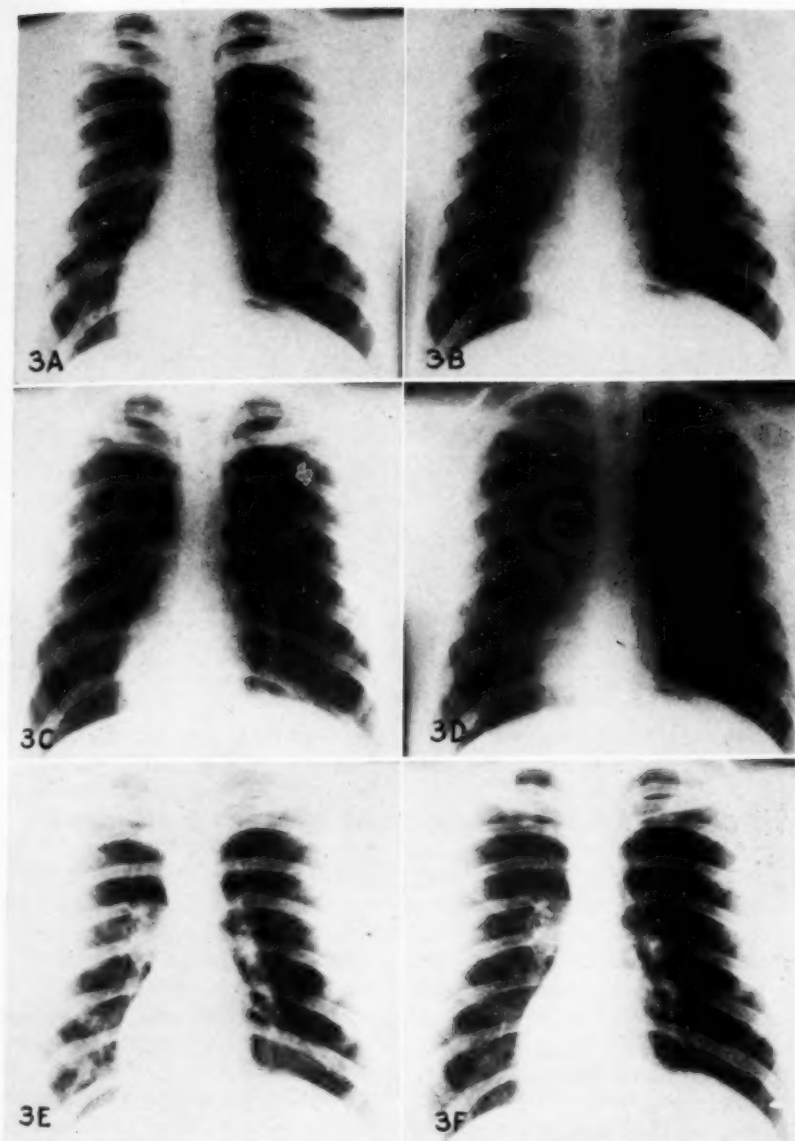
Fig. 3. Comparison of low *versus* high kilovoltage roentgenographic technics as applied to duplitized *versus* single emulsion films, showing results obtainable with and without a grid (*i.e.*, with the higher kilovoltages). The factors were as follows:

		Grid	Kv.p.	Ma.	Heat Units
A.	Duplitized film	No	65	85	5,525
B.	Single emulsion film	No	65	85	5,525
C.	Duplitized film	No	90	20	1,800
D.	Single emulsion film	No	90	20	1,800
E.	Duplitized film	Yes	90	40	3,600
F.	Single emulsion film	Yes	90	40	3,600

Note the greater contrast with the duplitized film. When low kilovoltage was used (A) and when the grid was used (E) the degree of contrast was considered excessive. Also, note the sharp detail obtained with the single emulsion films, particularly with the high kilovoltage and reduced exposure time (D and F).
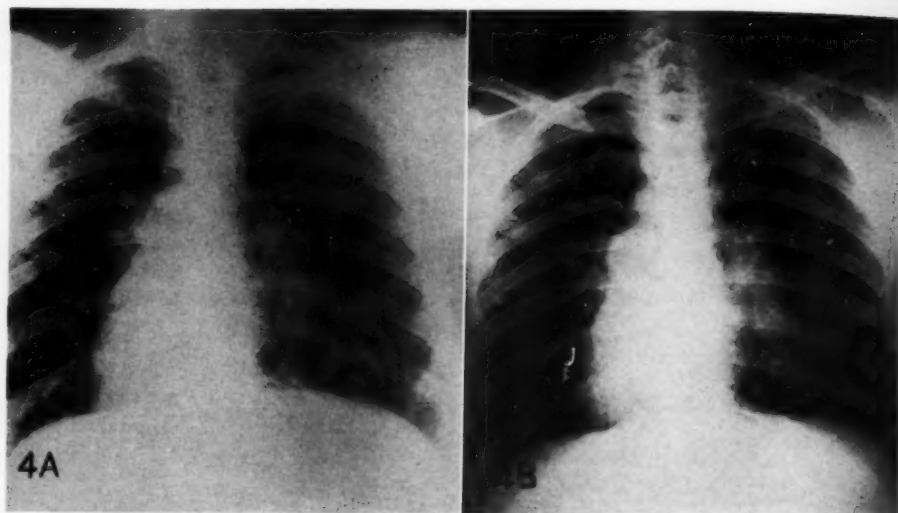
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Fig. 4.　Reproduction of 4 × 5-inch photograph of the fluoroscopic image.　Particularly when studied stereoscopically the hilar lymph nodes appeared large and discretely marginated.　B.　Reduction reproduction of a 14 × 17-inch roentgenogram of the same case.　With this latter technic the hilar lymph nodes were not nearly so conspicuous.　In proportion to the diameters of the thorax they appeared to be only slightly enlarged and their outlines were rather hazy.　Thus, the reduction provided in photographing the fluoroscopic image served to sharpen even the distorted image.

chest is projected to full coverage of the film, and unsharpness of detail occurs both because of the distortion factor and because of any spherical aberration in the lens and the inability to provide accurate focusing for all portions of it.　With focal screen distances greater than 48 inches, there too frequently results a loss of detail due to motion, because of the more prolonged exposure time requirement.　Moreover, greater punishment of the x-ray tube is involved so that heat unit capacities even greater than 700,000 per hour would be required for the average run.

It must be realized that these recommendations pertain only to conditions which prevail today.　With improvement of lens qualities, it will be possible to increase the focal-fluoroscopic screen distances.　There is, however, an advantage associated with the use of a relatively short focal-fluoroscopic screen distance such as 36 to 48 inches.　This advantage is the making conspicuous of minimal lesions, particularly those which are located at a distance from the plane of the fluoroscopic screen.　A favorable degree of distortion is produced by such focal-fluoroscopic screen distances. It has been said that most of the errors of interpretation associated with miniature film studies are due to exaggeration of findings rather than to failure to observe the densities.　For instance, a minimal parenchymal consolidation located in the mid-lung zones may present the appearance of a rather large bronchopneumonic process; an azygos septation may suggest a somewhat diffuse parenchymal infiltrate; Sibson's fascia may resemble a rather dense pleural thickening.　A good example is furnished by a case which, when studied with miniature films, presented the appearance of a lymphoblastoma but with conventional 14 × 17-inch film appeared more definitely as sarcoidosis (Fig. 4).　On miniature films, the hilar lymph nodes appear conspicuously large; thus projected, they may appear more sharply marginated than with conventional roentgenography.

RADIATION EXPOSURES INCURRED BY TECHNICIANS

The number of exposures required for accomplishing the examinations in an In-

duction Center (for 200 to 400 subjects), compel serious thought as to the quantity of radiation which may be received by the technicians, day after day. Two types of radiation are to be considered: (1) primary x-radiation included in the functional beam or possibly escaping from an inadequately protective tube housing; (2) secondary x-radiation which may emanate from walls or equipment affected by the primary beam or other radiation. Some

Dosimeter testings (with measurements in terms of milliroentgens) should be accomplished for each individual set-up. It is important to know the intensities of the radiation effective at one or another location of the room. Lead protective shields (*i.e.*, having x-ray opacity equivalent to no less than 1.5-mm. lead) should be used and should be so positioned as to be the most effective. Actual lead-lined booths are always to be recommended. Dosimeter
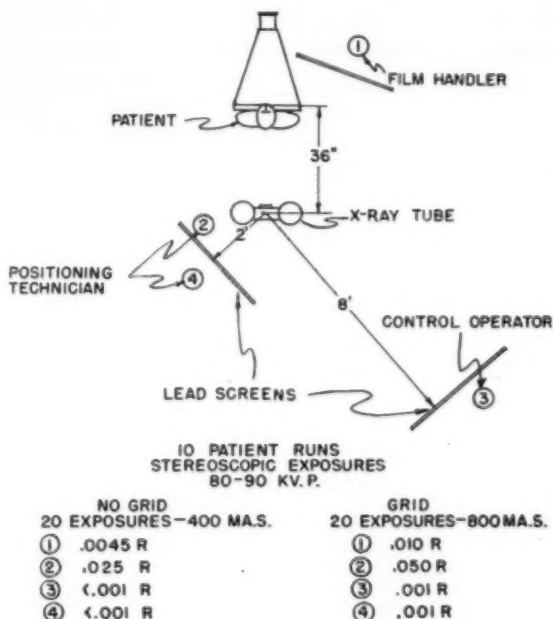
RADIATION EXPOSURES INCURRED BY TECHNICIANS

Fig. 5.

technicians are careless enough to expose themselves directly to the functional beam. This should never be allowed either in the course of performing their duties or for the making of trial exposures. Some technicians are not cognizant of the fact that at least minimal quantities of x-radiation may escape through even a so-called "ray-proof housing." Many are prone to ignore the secondary radiation which can be expected to emanate from the patient, the walls of the room, and interposed objects.

testings may indicate the advisability of rearranging the equipment so as to reduce the secondary radiation (*i.e.*, back-scatter) receivable by one or another technician. They may indicate the advisability of changing the position of lead shields or booths. At least the facts pertaining to radiation hazards should be revealed.

Such testings have been conducted in several of our centers. Though the results vary somewhat, the sketch contained in Figure 6 indicates average values. It

can be seen from these results that with consideration of 200 to 400 individual stereoscopic examinations in a day an excessive exposure would be received by a technician standing unprotected and within a few feet of the x-ray tube (even though he be not in the functional beam and even though the tube be of a type generally recognized as "ray-proof").[6] With protection by the lead shield and greater distance, the exposures are reduced to minimal values, some of which (allowing for 200 to 400 examinations per day) would closely approximate the recognized tolerance dose of 0.1 r per day.

SUMMARY

The importance of examining very completely every candidate for the Army and providing film records of chest findings is emphasized. Both epidemiological and legal aspects are considered.

Nine methods of roentgenologic procedure are cited. These are evaluated in terms of trust for single case study, trust for mass studies, co-ordination with other examinations, future reference, unit cost per examination, and initial cost of auxiliary equipment. Such considerations have led to the official adoption of the stereoscopic technic with a 4 × 5-inch film.

Certain technical aspects are discussed as they pertain to large-scale procedures and present-day equipment. For the intensity of radiation, 200 milliamperes are believed practical. The x-ray tube should be of a design to withstand high heat— no less than 700,000 heat units per hour. Single emulsion x-ray films, rather than the conventional duplitized type, are recommended for two reasons: increasing the sharpness of detail and decreasing the contrast characteristics. Kilovoltages higher than those conventionally used for chest roentgenography are favored for reduction of exposure times, reduction in contrast effects upon the image, and reduction of punishment imposed upon the x-ray tube. The use of a wafer type of grid is recommended for very thick chests and when kilovoltages in excess of 85 are required. For the present-day lens a relatively short focal-fluoroscopic screen distance, 36 to 48 inches, is believed best.

It is pointed out that with the handling of 200 to 400 such roentgenographic examinations each day, there is a definite radiation hazard for the technicians in the exposure room and unless the equipment be properly positioned and lead protective shields be used, it is likely that more than 0.1 r, the recognized daily tolerance dose, will be received by them.

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March Fracture[1]

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THE TERM "march fracture" is applied to fracture of a metatarsal occurring in persons who have experienced prolonged and repeated foot strain, but who have not suffered a single obviously severe injury. This syndrome was brought into prominence during the first World War, although it had been described as early as 1855 by Breithaupt, a Prussian military surgeon, who named it "Fussgeschwulst." Stechow (1897) is credited with first making the diagnosis by means of the roentgenogram, and demonstrating the presence of a fracture. Since then the subject has been thoroughly discussed in the European literature. Maseritz (2) has compiled an excellent bibliography of these writings.

A few papers have appeared in the American literature in the last decade, notably by Speed and Blake (4), Meyerding and Pollock (3), and Zeitlin and Odessky (5). In spite of this, the post-war generation of physicians is still prone to overlook this disability, as is evidenced by the fact that we have recently seen a number of cases in which the correct diagnosis was not suspected until roentgenograms were made.

Hundreds of thousands of young men are now entering the Army. In the course of their military service these men will walk distances much greater than they were accustomed to walking in civil life, and as a result, this otherwise infrequent clinical entity is certain to increase. The author saw only one case in three and a half years prior to entering on active duty with the Army, but has seen 9 cases in six months at the Station Hospital, Fort Jackson, S. C. A search of the files revealed one additional case.

We wish, therefore, again to call attention to this syndrome, to review the clinical findings and symptoms of "march foot," and to demonstrate the various roentgenographic appearances.

ETIOLOGY

The pathogenesis of these fractures is not clearly understood. This fact is best demonstrated by the multiplicity of theories advanced by different authors. Periostitis, myositis, disturbed circulation, pes planus, a short first metatarsal, bacterial or trophoneuritic factors have been variously suggested as the underlying or predisposing causes. We do not propose to discuss these hypotheses, but point out that all patients give a history of prolonged and repeated foot strain, such as would be sustained by marching, hiking, or standing for long periods of time. Brandt (1) has ably summarized this by stating that these fractures are the result of rhythmically repeated, subthreshold mechanical insults, acting by summation, to a point beyond the capacity of the bone to bear stress. (The ability to bear stress may be reduced by the other factors mentioned above.)

This overload of the functional capacity of the bone is the direct cause of the fracture, whatever the predisposing conditions. Therefore, any person complaining of foot pain whose feet have been subjected to such conditions, in military or civil life, should be suspected of having a "march foot."

CLINICAL FINDINGS

The onset may be abrupt or insidious. Although in some cases the patient insists that the first pain experienced was severe and sharp, the onset in the majority of cases is gradual. The first symptom is usually a slight discomfort in the metatarsal area, which slowly increases in severity and is manifest only when the body weight is placed on the foot. The patient walks

with a limp to lessen the weight borne by the metatarsals. Relief is obtained by rest and elevation of the foot.

This pain and its accompanying tenderness are usually localized to the site of the fracture. Motion at the ankle joint or the toes is not painful. A definite edema of the dorsum of the foot soon appears but will disappear with rest. Later this is replaced by a smaller, localized, harder swelling, *i.e.*, the callus. Crepitus is not felt.

ROENTGEN EXAMINATION

Technically perfect roentgenograms, showing maximum detail, are needed to make the diagnosis early in the course of this ailment. This point cannot be emphasized too strongly. For this reason cardboard film holders should be used, preferably with non-screen film, and the smallest focal spot available should be employed. The target-film distance should be at least 36 inches to minimize distortion, and the foot must be firmly immobilized during the exposure. At least two views, the postero-anterior and the oblique, should be taken.

On the basis of the changes seen on the roentgenograms, we may divide this syndrome into four stages. It is most important to remember that a roentgenogram taken during the first stage (within the first seven to ten days after the onset of symptoms) may show no pathologic changes. Because the fracture line is narrow and often incomplete, and because no displacement occurs, it is difficult to demonstrate the fracture. Even on technically perfect roentgenograms the fracture line may not be visible, but the better the quality of the roentgenogram, the better the chance of demonstrating the fracture. If the fracture line is demonstrated, the diagnosis is obvious.

In the second stage, from one to three weeks after the onset of symptoms, a loosely calcified and fuzzy callus is seen in the shape of a spindle or cylinder around the shaft of the second or third metatarsal. Any other location is very rare. At this time the fracture line is visible in most cases. If the foot has not been placed at rest immediately after the onset of symptoms, the loose callus is surprisingly abundant.

In the third stage, after immobilization in a plaster cast, the callus becomes denser, more circumscribed, more sharply defined, less bulky, and looks "harder." This takes another three to six weeks. The fracture line is often still visible.

In the fourth and final stage, several months later, the only remaining sign is a slight thickening of the cortex.

Roentgenographically considered, march fracture must be differentiated from osteogenic sarcoma and Ewing's tumor. The differentiation may be quite difficult, especially if the patient is seen in the second stage, with a spindle of callus around the metatarsal. In such cases recourse to the history must be had, and careful inspection of the roentgenogram for a narrow fracture line should be made. If it is still impossible to separate these entities, a cast should be applied for three weeks, then removed and the patient re-examined. If one is dealing with a march fracture, the callus should be smaller, denser, and more circumscribed; whereas in the case of a neoplasm the spindle would be of the same or larger size. It should further be remembered that the foot is not a common site for osteogenic sarcoma or Ewing's tumor.

TREATMENT

The treatment is that of any fracture in this area; namely immobilization, preferably in a plaster cast, for three to six weeks, followed by physiotherapy.

CASE REPORT

Complete case histories could be taken in 9 of the 10 cases seen in the Station Hospital. Two men had been soldiers for over eighteen months. Two had been laborers and 6 had had sedentary jobs before induction. All of the men were well nourished. They ranged from slender to very heavy in build. Excluding the 2 Regular Army soldiers, the length of service before the onset of the symptoms varied from three

Figs. 1-4.   March fracture.

Fig. 1.   Nineteen days after onset.   A faint, lightly calcified callus is seen around the distal end of the third metatarsal.   A narrow, incomplete fracture line is present near the distal end of the callus.   This is the second stage.

Fig. 2.   Twenty-nine days after onset.   The callus has increased in amount but is still fuzzy. The fracture line is barely visible.   A cast was applied immediately after this roentgenogram was made.

Fig. 3.   Two months after onset, and immediately after the cast was removed.   The callus is smaller, denser, and "harder."   It is now sharply outlined.   The fracture line is not visible. This is the third stage.

Fig. 4.   Three months after onset.   The excess callus has disappeared.   The only remaining finding is a thickening of the cortex.   This is the fourth stage.

to nine months. These men, therefore, had already completed the preliminary course of training and were in good physical condition.

Of the 10 cases seen at the Station Hospital, only 2 were correctly diagnosed before the roentgenograms were made, in spite of the fact that the history of the present illness was clear cut in every instance. The following case history is presented as a typical example of this syndrome.

M. P., a 27-year-old laborer, entered the Army as a selectee on Jan. 10, 1941. He was assigned to an infantry regiment and given the usual course of training. He had no trouble until June 22, 1941, when, about half way through a 27-mile march, he began to notice pain on the plantar surface of the right foot. This pain gradually became more severe but was present only when the right foot carried the body weight. After a rest he was able to complete the march but experienced considerable pain. Rest and soaking in hot magnesium sulphate solution gave some relief. In the ensuing days, pain was present on walking, but since there were no further long marches, the man continued on duty. On July 10, however, he reported to the dispensary. On July 11, nineteen days after the onset, a roentgenogram (Fig. 1) showed fuzzy, loose callus formation and a narrow, incomplete fracture line in the distal portion of the third metatarsal. The patient was relieved from duty and allowed to rest the foot. On July 21, another examination (Fig. 2) revealed the callus formation to be considerably increased in amount, and the fracture line to be barely visible. At this time the patient was admitted to the Station Hospital and a plaster cast was applied. Following removal of the cast, on Aug. 19, the callus was seen to be less bulky, more dense, and sharply circumscribed (Fig. 3). The fracture line was no longer visible. There was now no pain, and the patient was returned to duty. A follow-up roentgenogram (Fig. 4) on Sept. 19 showed only thickening of the cortex. The patient was symptom-free, and has since had no recurrence of pain.

SUMMARY AND CONCLUSIONS

Attention is drawn to the syndrome of "march fracture." This entity will undoubtedly be seen more frequently as the military forces are expanded. Ten cases have been seen by the author. One typical case history is presented.

The important diagnostic points are: absence of a history of direct trauma; pain on the plantar surfaces of the metatarsals with each step; localized tenderness over the second or third metatarsal; edema of the dorsum of the foot. The onset may be sudden or gradual.

This syndrome known as "march foot" or "march fracture" may be divided into four stages on the basis of the roentgenographic findings. During the first ten days following the onset of symptoms, an incomplete, narrow fracture line may be present, but failure to demonstrate such a fracture line does not exclude a "march fracture." In the second stage, from one to three weeks after onset, a spindle-shaped callus is seen around the second or third metatarsal and the fracture line is often visible. The amount of callus is usually large in proportion to the extent of the injury. In the third stage, after immobilization, the callus is smaller, denser, more sharply circumscribed, and the fracture line may still be visible. In the fourth stage, the only finding is a slightly thickened cortex. A higher percentage of these fractures can be diagnosed in the first stage if technically perfect roentgenograms can be obtained.

The treatment is the same as for any fracture in this region.

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The Correlation Between Roentgen Dosage and Lymphoid Cell Migration in Tissue Cultures[1]

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CULTURES OF fibroblasts have been used by Strangeways and Oakley (1923), Strangeways and Hopwood (1926), Canti and Donaldson (1926), Canti and Spear (1927), Laser and Halberstaedter (1929), Canti (1929), Spear (1931, 1932), Cox (1931), Faber (1935), Lasnitzki and Lea (1940), and others, to study the effects of radiation. Inhibition of growth rate and the rate of mitosis have been taken by these investigators as an index of the effects of radiation. Stenstrom and King (1934, 1937) and King and Stenstrom (1937) have used the migration of lymphocytes from mammalian lymph nodes *in vitro* to determine the effects of spaced dosage of x-rays and to test the Bunsen-Roscoe law for roentgen rays.

The present investigation was undertaken to determine the effects of a wide range of x-ray dosages on the activity of lymphoid cells *in vitro*. For this study, fragments of adult rabbit mesenteric lymph nodes were employed exclusively. The lymph node for each series of cultures was taken from the same animal from which the blood for the serum and plasma was obtained. After the blood was drawn the animal was immediately killed and skinned. In a planting cage the node was removed and placed in a Maximow slide in a Petri dish. The node was then cleaned of all fat and connective tissue and was fragmented, the fragments being transferred to a Petri dish containing Tyrode solution.

The fragments, 1.5 to 2.5 mm. in diameter, were carefully chosen in pairs according to size, shape, and color. One of each pair was used as a control, the other as the experimental tissue. In this way each control culture has a visually identical experimental culture.

Extreme care in selecting "matched fragments" is very important in tissue culture studies. A lymph node is not a histologically homogeneous organ. The cortex is generally a densely packed mass of lymphocytes supported by the reticular framework. The medulla has a more open structure with fewer lymphocytes. The qualitative and quantitative aspects of the migration rims from fragments of cortex and medulla are different. Consequently, unless comparable fragments of either cortex or medulla are present in the control and experimental cultures, the experimental error will be greatly increased. Check plants in which two control series were used showed that the use of "matched fragments" gives reliable quantitative data. The experimental error of two control series seldom exceeded 5 per cent.

The heparinized plasma, serum, and chick embryo extract were prepared according to the methods described by King (1930). Two c.c. of serum were used to extract one six-day chick embryo.

The selected fragments were transferred to Carrel D_5 flasks. All the control fragments of a series were placed in one flask and all the experimental fragments in another. Three to 5 c.c. of autogenous serum were added to each flask. The flasks with the fragments were placed in a special incubator and exposed to the desired x-ray dosage at a temperature of 37.5° C., the control flask being protected by approximately one-half inch of lead plate. After irradiation was completed, the fragments were washed free of loose cells and serum, and planted as individual cultures.

The cultures were planted in one drop of heparinized plasma and three drops of serum-chick embryo extract. They were prepared as Maximow "double coverslip" preparations and incubated as lying drops

at 37.5° C. in a special down-draft incubator (King, 1937).

Observations and measurements on the living cultures were made at the end of twenty-four hours of incubation. Measurements were made with a microscope fitted with an ocular micrometer at magnification 60×. The readings are given in eye piece units (114 eye piece units equal 1

All the x-ray exposures were made under the following conditions: A water-cooled x-ray tube with heavy glass wall installed in a large lead drum supplied the radiation. A 30 ma. mechanically rectified current was used at a potential of 200 kv. peak as measured by a sphere-gap. The rays passed through a 1 mm. aluminum filter and a larger permanently installed ioniza-
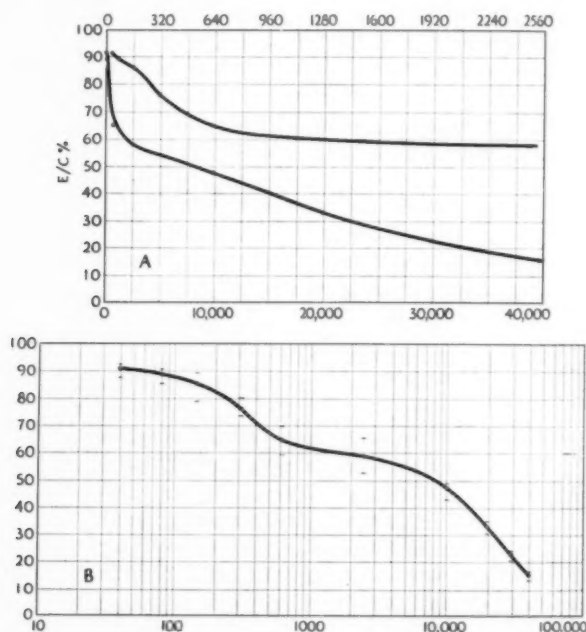

Fig. 1. Curves showing the correlation between x-ray dose in roentgens and migration of lymphocytes in tissue cultures twenty-four hours after irradiation. 100 E/C = migration of the irradiated cultures expressed in per cent of the migration in the control cultures. In A, upper figures refer to the upper curve, the figures below to the lower curve. In B, logarithmic scale is used for the complete curve. The bars in this figure show the limits of variation for each dosage level.

mm.). In making the measurements the widest point of cell migration was selected. The distance from the edge of the fragment of tissue to the outer periphery of the rim of migrating cells was recorded and used as the maximum migration distance of the cells in each culture. Twelve fragments were used in both the control and experimental series in each plant, and the average maximum migration for each plant was determined.

tion chamber which corresponded to an additional 1 mm. aluminum. The half-value layer of these rays was found to be 0.28 mm. Cu and the output at 50 cm. target distance 162 r per minute when the last measurements were made. The rays had to pass through the top cover of the incubator, which consisted of cardboard 1 mm. thick, and the top of the Carrel flask. This additional filter had little influence on the hardness of the rays but must, to-

TABLE I: TYPICAL RANGE OF FLUCTUATION OF INHIBITION WITH THE SAME TOTAL DOSAGE

No. of Cultures	Length of Radiation	Dosage in Roentgens	Average Migration: Controls	Average Migration: Experimentals	100 E/C*	Per Cent Inhibition
24	30 sec.	78	149.5	136.2	91.1	8.9
24	30 sec.	78	163.0	147.0	90.2	9.8
24	30 sec.	78	182.0	157.0	86.2	13.8
24	30 sec.	78	192.0	174.0	90.6	9.4
24	30 sec.	78	167.1	147.7	88.4	11.6
24	30 sec.	78	154.0	132.0	85.7	14.3
24	30 sec.	78	195.3	176.9	90.5	9.5

TABLE II: SUMMARY OF ALL CULTURES IN EACH OF THE DOSE LEVELS

Length of Radiation	Total Dosage in Roentgens	Number of Cultures	Average Migration: Controls	Average Migration: Experimentals	100 E/C*	Per Cent Inhibition
15 sec.	39	96	152.27	138.80	91.2	8.8
30 sec.	78	168	171.82	152.97	89.0	11.0
1 min.	155	240	152.14	131.28	86.3	13.7
2 min.	310	96	168.25	129.00	76.7	23.3
4 min.	620	240	159.06	103.31	65.0	35.0
16 min.	2,480	144	187.53	109.15	58.2	41.8
64 min.	9,920	120	182.60	86.00	47.1	52.9
128 min.	19,840	48	136.00	45.00	33.1	66.9
192 min.	29,760	48	127.25	28.50	22.3	77.7
256 min.	39,680	48	137.00	21.75	15.9	84.1

*100 E/C = migration of irradiated cultures expressed in per cent of the migration in control cultures.

gether with the other portions of the flask, its fluid content, and the wood structure below, influence the amount of radiation to which the fragments were exposed. The measurements showed that the flask absorbed 20 per cent of the radiation and thus one side of the flask about 10 per cent. When the small ionization chamber replaced the flask in its position during exposure a reading of 180 r per minute was obtained. If 10 per cent is subtracted due to the absorption of the glass, this would give 162 r per minute. It is impossible to state from these measurements the exact dose, but it should certainly not differ much from 160 r per minute.

As the experiments were carried out over a period of three to four years, the x-ray output changed somewhat. It was, of course, determined at different periods. In Table II the length of exposure, as well as the number of roentgens, is given. Nothing but the length of time of the exposure was changed during these experiments. All other conditions were as far as possible kept the same. Errors in measuring the total dose due to fluctuation in x-ray output and to determination of exposure time by means of a stop-watch should

not amount to more than a few per cent. These errors must be negligible in comparison to the biological variations, as a doubling of the dose resulted in a moderately small per cent change in the migration zone.

After the observations were made on the living cultures they were fixed in Zenker-formol fixative to be studied histologically later. Some indication of the condition of the migrated cells could be ascertained from the living preparations. At this time we wish to state that only after 40,000 roentgens did none of the lymphoid cells appear to be ameboid at forty-eight hours. With smaller dosages ameboid cells were seen at a similar time.

It must be pointed out that x-rays not only decrease the width of the migration zone, but the rims also become progressively thinner as a higher dosage is used until, at the upper limits, only a few cells, in comparison to the controls, migrate.

The average spread of inhibition in all dose levels was approximately 6 per cent. In the 30-second dose the range was 5.4 per cent. The seven experiments at this dose are listed in Table I. The average inhibition produced by the various dosages is shown in Table II and Fig. 1.

It will be noted that a dose of 39 r produces an inhibition of 8.8 per cent. Inhibition increases rapidly with increased dose up to about 620 r and much more slowly above this level.

The fact that with large doses the migration zone is thin, as well as narrow, and in addition seems to be composed chiefly of larger cells suggests, as a tentative explanation of the curve, that sensitive cells are being inhibited up to doses of about 620 r, while much larger doses are required to inhibit the more resistant cells. It would be necessary to suppose that the more resistant cells migrate more slowly and that their response, if any, to small doses is masked by the more rapidly migrating sensitive cells.

Whether this assumption is true will be determined by study of stained serial sections of cultures in all dose levels. It should be noted that measurements and observations are made on the living material at magnification of 60×. Under such conditions it is not possible to differentiate closely related cell types. Thus, while it is evident that the very resistant cells are larger than the sensitive types, it is not possible to identify the exact type.

The possibility that the greatly reduced number of cells per unit volume present in the migration zone of heavily radiated cultures might be a factor in slowing the migration rate of the remaining resistant cells must be considered in the final interpretation. The histologic studies upon which this interpretation will be based are in progress.

We assume tentatively that there are present in mammalian lymph nodes two groups of cells which differ widely in their sensitivity to x-rays.

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Radiation Effects on Blood Vessels[1]

Part I: Erythema; Edema

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To account for the effects of radiation on the blood vessels three main theories have been advanced: the metabolic, the neuromuscular, and the cellular.

According to the *metabolic* theory the vascular effect of the rays is a secondary one, brought about through metabolic changes in the adjacent tissues. There is, however, some question as to the exact nature of the agent set free in the irradiated tissues, to which the effect on the blood vessels is attributable (Wetterer, Schwarz, Lewis). Lewis, whose view is the most widely accepted, believes it to be of the nature of histamin (H-substance), and it is undoubtedly true that the vascular response to irradiation bears some resemblance to that induced by the cutaneous application of histamin and that mechanical and thermal irritants, as well as light, produce a comparable effect through the liberation of this substance.

There are, nevertheless, numerous objections to the acceptance of the histamin theory. First, there are a number of agents, particularly among the salts of heavy metals, quite unrelated to histamin, which are capable of producing erythema and other vascular phenomena. In the second place there is no reason to assume that the blood vessels are exempt from the rules governing the reaction of living tissues in general to radiation. Furthermore there are certain differences in the erythema following irradiation and that produced by histamin, especially its longer latent period, and its rhythmic or wave-like character. Also to be taken into consideration are the absence of the diffuse reflex erythema observed with histamin, the fact that roentgen and radium rays are capable of producing not only a dilatation of capillaries,

which is followed by erythema, but also a narrowing of their lumina preceding the erythema, and the failure as yet to demonstrate any increase of histamin in the irradiated tissue such as has been shown to exist following ultraviolet irradiation (Ellinger).

As to this last, it may well be that different mechanisms are involved in the erythema produced by visible and ultraviolet light and that due to x-rays and radium, the former being a photo-chemical and the latter a photo-electrical effect.

According to the *neuromuscular* theory the changes observed in irradiated blood vessels are produced by the direct action of the rays. Under their influence certain elements of neuromuscular character may be responsible for constriction or dilatation of the vessels, but whether it is the nerves that are primarily affected or the muscle cells is a matter of dispute (Krogh and Vintrup, Ricker, Glauber, Müller, David and Gabriel). Either assumption is open to numerous objections both from the standpoint of radiobiology and anatomy and physiology.

As to the radiosensitivity of nerves and muscles, it may be stated that doses sufficient to produce erythema and allied vascular phenomena have proved ineffective in these tissues. Clinical and experimental observations show that only doses leading to a marked inflammation produce disorders or alteration of nerve or muscle tissue. It is furthermore known that a neuromuscular stimulus induces an immediate response, *e.g.*, constriction, whereas the vascular phenomena following irradiation take place only after a period of latency, which may last a week or longer. The anatomical and physiological objections to the neuromuscular theory have to do with

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the structure of the capillaries, which have been shown to be free of any neuromuscular regulation.

According to the *cellular* theory, neither the tissues surrounding the vessels nor the neuromuscular apparatus governing the larger vessels but the tissues composing the irradiated blood vessels themselves are responsible for the radiation effects. These effects are thus, in the last analysis, to be considered as the sum of the individual effects produced in the various tissues forming the vessels. It remains to discuss the chief vascular phenomena produced by radiation and try to determine the contribution of the individual tissues to each of them.

GENERAL CHANGES IN IRRADIATED CELLS

The living cell represents a mosaic of colloidal substances suspended in an aqueous medium. The colloidal substances are constructed of highly complex proteins, mainly of two kinds: globulins with a high specific weight and albumins with a low specific weight. Under the influence of radiation the normal ratio of 2:1 between the globulins and albumins becomes altered, the amount of globulins decreasing and that of albumins increasing (Heilbrun and Mazia). As a consequence of this change, representing the final result of an ionizing process induced by rays, proteins of large molecular size are replaced by those of small molecular size. With this transformation, the osmotic pressure (that is, the power to attract water) increases, while the viscosity of the cell gradually diminishes (Feichtinger). Since albumins are more hydrophilic than globulins, the cell absorbs water and swells. The process of swelling concerns the whole cell, including nucleus, protoplasm, and the ectoplasm and endoplasm composing the latter. The ectoplasm, forming the surface of the cell, possesses the properties of a membrane, especially that of semi-permeability. It is highly permeable to water and salts, but impermeable to proteins. When the osmotic pressure rises, the cell becomes more permeable and more fluid enters the protoplasm from the neighborhood. Similarly, the fluid is attracted from the protoplasm by the nucleus. The swelling which occurs as a result of these physical-chemical changes is the first visible effect in irradiated cells.

This same process may be observed microscopically in irradiated *tumor* cells. It may be mentioned that, according to Sugiura, "the radiosensitivity of mouse sarcoma is markedly increased by injections of distilled water (a strong hypotonic medium), following local treatment with roentgen rays." On the basis of Sugiura's experimental results, Failla developed an interesting theory concerning the mode of action of rays with the phenomenon of swelling as its center.

This relationship between decomposition and osmotic pressure explains the fact, which Packard first pointed out, that the more radiosensitive a tissue, the stronger the swelling effect following irradiation. This connection is obvious, since radiosensitivity is only another term for the decomposability of a tissue, and the swelling is the immediate result of the increased osmotic pressure.

GENERAL CHARACTERISTICS OF THE RAY ERYTHEMA

If the swelling occurs in a cell of globular configuration, a uniform enlargement in all directions results. An even distribution of pressure in all directions may also occur in cells of cubical shape. The endothelial cells of the blood vessels, however, are of rhomboid form with diameters increasing in size in the following order: a frontal diameter, from inside to outside; a transverse diameter in the direction of the circumference of the blood vessel (usually curved); a longitudinal diameter in the direction of the blood stream. The effect of expansion of the fluid inside the cell will manifest itself in different degrees in the individual diameters. Swelling will first take place in that diameter in which the cell is first filled to its greatest extent; hence, in the shortest diameter, the frontal, from the blood to the tissue through which, under

pathological conditions, effusion and emigration take place. As the endothelial cells increase in size in that direction, they will protrude into the lumen of the blood vessel, and *narrowing* of the lumen will occur. Vintrup, in his description of the contracted capillaries, expressly stresses the fact that the nuclei of the endothelial cells in this state project into the lumen. This is because the nucleus lies in the frontal diameter of the cell and therefore swells very early following irradiation. Subsequently the lumen may be narrowed to a degree making the capillaries invisible to microscopic inspection (Müller, Siedamgrotzky, Lazarew, Glauber, Turano) (Fig. 1).

Stricker was first to emphasize that the narrowing of the lumen of the capillaries, which he had observed following electrical stimulation, is associated with a thickening of the vessel walls. Radiation effects on the capillaries confirm this view. Consequently it becomes clear that tone means turgor, dilatation means inhibition, and contraction means shrinkage of the endothelial cells.

If the radiation effects continue, so that more and more fluid enters the endothelial cells, the swelling in the frontal diameter will soon be followed by a distention of the cell in the direction of the next longer diameter; that is, in the transverse diameter. Distention in this diameter leads to an enlargement of the cell and thus to *dilatation* of the lumen. Vintrup described the endothelial cells in the dilated capillaries as follows: "The cells are large and thin and their nuclei are thin, oval disks which project only very slightly, if at all, in the inside of the capillaries," while in narrowed capillaries, as has been mentioned, the endothelial cells are small and thick on account of the protrusion of the nuclei into the lumen.

If, under the influence of the rays, the influx of fluid into the altered endothelial cells is continued, the cells distend also in the longitudinal diameter, so that the capillaries appear not only wider but also *longer* (Schugt, Lazarew, Turano). This

contributes to a further expansion in the transverse diameter, and thus to an increased dilatation of the capillaries which may amount to a redoubling of the lumen.

With dilatation of the capillaries the minute vessels, previously empty and mi-

1. Swelling in the frontal diameter.

Normal capillary with the lumen = 1.

Lumen of the capillary is narrowed = 1, owing to the widening of the endothelial cells.

2. Swelling in the transverse diameter.

Normal endothelial cell.

Endothelial cell enlarged. As a consequence the lumen of the capillary is dilated.

3. Swelling in the longitudinal diameter.

Two adjacent endothelial cells with the normal broad diameter = d

Endothelial cells elongated. As a consequence the capillary is elongated and dilated. The broad diameter now = d.
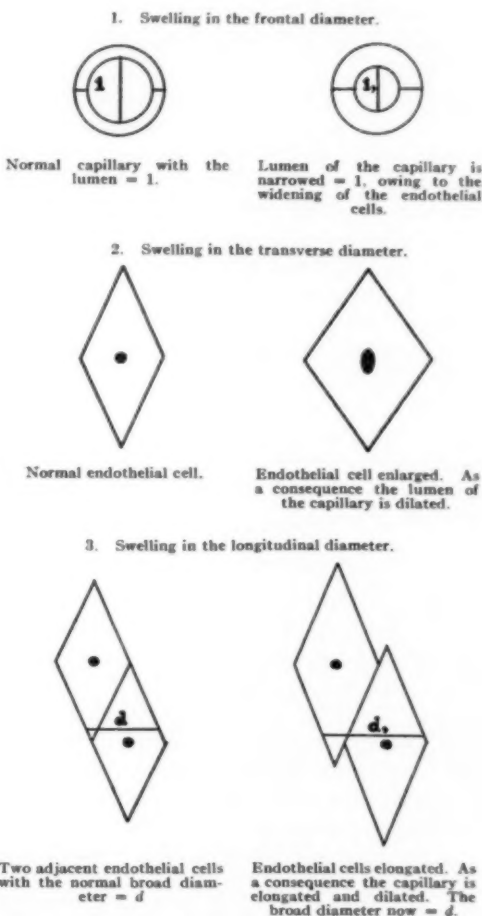
Fig. 1.   Radiation changes in the endothelial cell

croscopically invisible, fill themselves with blood and thus become visible microscopically. When the dilatation effect is continued, and the capillaries become more closely packed with erythrocytes, a *hyperemia* results and the vessels can be seen by the naked eye. A criterion of the biological ray effectiveness clinically of high value, the *skin erythema*, results. As long

as the hyperemia is limited to the superficial capillaries of the papillary region, the redness of the skin remains slight. Its intensity increases as the more deeply situated subpapillary plexus also becomes dilated. The higher the dose applied, the more intensely does this complex network become involved.

While in the capillaries, consisting solely of endothelial cells, the latter may swell and dilate in any direction, this is obviously impossible in the arteries and veins, in which the muscular coat, elastic fibers, and connective tissue encircling the endothelium offer resistance passively and actively to any increase in the lumen. The tone of the muscle tissue is controlled by nervous impulses originating in vital nerve centers. The strength of the forces regulating the muscle tone of the arteries may be judged from the fact that "the terminal arterioles are narrower than the succeeding capillaries, because of the presence of well developed smooth muscle cells in their walls" (Zweifach). Under these circumstances it is conceivable that arteries and veins do not become distended when the osmotic pressure is increased within the irradiated endothelial cells. In contrast to the capillaries, there is no swelling or enlargement in the transverse or longitudinal diameters. Consequently there is no dilatation of the lumen nor elongation of the irradiated arteries and veins. The only effect consists of a swelling in the frontal diameter of the endothelial cells. Protruding into the lumen, the swollen cells cause a concentric *narrowing* of the vessel as a final result. Thus it is obvious that, while the narrowing of the lumen in the capillaries represents merely a transitory phase, followed shortly by a much more marked and prolonged dilatation, associated with an elongation of the hair vessels, in the arteries and veins the narrowing of the lumen is the only alteration which the rays produce. As a corollary to these observations, it might be concluded that if the arteries were situated at the site of the capillary bed, irradiation would lead to pallor instead of redness of the skin.

The statement that the arteries are not dilated during the ray erythema is substantiated by any careful examination of the irradiated vessels. Despite all that has been said about the dilatation of blood vessels and hyperemia as effects of irradiation, an actual dilatation of the true arteries has never been established. Such impressions may be derived only from the observation of vessels of border-line character, such as the precapillary arterioles. In true arteries the only finding following exposure to rays is either a normal or a narrowed lumen, depending on the time of examination. This can be demonstrated readily *in vivo* in the eyeball. Ophthalmoscopic examination of the fundus following irradiation shows that the arteries of the retina are never dilated, no matter what the dose applied, but they are sometimes narrowed.

The narrowing of lumina of the small arteries can be observed experimentally in the crest of the cock, which becomes pale after irradiation (Zurhelle). Histologically it can regularly be seen in the skin (Gassmann, Scholz, Thiess, etc.) and has been repeatedly described in the brain (Lyman, Kupalov, and Scholz; Colwell and Gladstone).

The strict limitation of the erythema to the field of irradiation provides another strong link in the chain of evidence that the arteries do not play a notable rôle in the formation of the ray erythema.

This becomes clear when one recalls the difference between the erythema following irradiation and that following the application of a drop of histamin on the skin. Histamin produces first a sharply localized redness, which subsequently spreads far beyond the borders of the drop. It appears from the various experiments of Lewis that in this case the first erythema is caused by a direct action on the capillaries while the second is caused by an axon reflex to the arteries. The hyperemia caused by dilatation of the arteries is thus not strictly limited to the area of direct action of the causative agent. The same also holds true when the skin is influenced by heat or is

struck or rubbed. This sequence of events is easily understood in view of the distribution of the blood vessels in the skin (Fig. 2). The most superficial vessels, the capillaries, are extremely narrow and do not communicate with one another. Consequently, as long as the capillaries only are affected, the erythema will correspond exactly to the number of these which are exposed to the rays and to the field they occupy. The erythema will retain its localized character also when to the dilatation of the capillaries is added the enlargement of the subpapillary plexus, since this runs parallel to the surface of the skin so that only the portion directly exposed to the rays can dilate.

The erythema would, however, immediately lose its circumscribed character and spread beyond the field of irradiation if the arteries next to the subpapillary plexus were also affected by rays. These arteries, the so-called "arched arterioles," unite the arterial subpapillary plexus with the more deeply situated arterial cutaneous plexus. Along their vertical pathway from the latter vessels to the former, they branch off into arcades running laterally from the stem. When the stem dilates, the laterally running branches of necessity also dilate; the overlying skin becomes hyperemic, and the erythema loses its sharply localized character.

Since the erythema of radiation under no circumstances extends beyond the borders of the irradiated field, the conclusion must be drawn that the rays do not exert any dilating effect upon the arched arterioles. This is to be explained neither by their position nor their caliber, but solely by the fact that "these arched arterioles are the smallest vessels in the skin that possess a strong muscular coat," as Lewis states.

It may be added that if rays actually had a dilator effect on the arteries, the extension of the erythema would depend not on the size of the field irradiated, but on the caliber and distribution of the arteries affected. This effect, furthermore, would be greater the larger the dose given. Ex-

perience has shown the contrary to be true. The larger the dose given and the more intense the subsequent erythema, the more endangered are the deeply situated tissues. This danger does not exist in the case of the erythema produced by sunlight, ultraviolet rays, and many other agents. Nor would such careful consideration be required if the rays caused a hyperemia in the deeper arterial plexuses as they do in the superficially situated capillaries. The serious nature of an intense erythema fol-
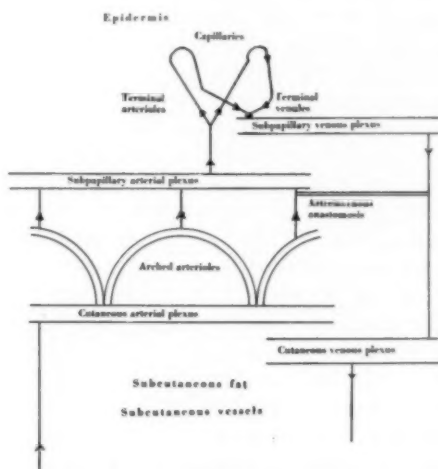

Fig. 2. Schematic drawing of blood vessels of the skin

lowing radiotherapy stems from the fact that the erythema due to dilatation of the superficially situated capillaries is associated with a constriction of the more deeply lying arteries. Eventually, if arteriolar constriction is complete and of long duration, there may result ischemia of the tissues supplied by these vessels, which may in turn be followed by necrosis and ulceration.

It appears from the preceding analysis that the skin erythema following roentgen or radium irradiation is due solely to the dilatation of the capillaries, and is not the result of an increased flow of blood from dilated arteries. On the contrary, while the capillaries are dilated, the arteries may be narrowed.

THE THREE ERYTHEMA WAVES

Even in the early days of radiotherapy it was observed that under certain circumstances irradiation was followed by two erythemas at different time intervals (Holzknecht, Kienboeck, Köhler, Wetterer, etc.). In 1924 Miescher described a third erythema and developed the conception that the radiation erythema occurs in "waves," so that it may be regarded as a rhythmical or periodical phenomenon. This view has been corroborated for roentgen rays by Lazarew, Pohle, Hess, Schreuss, Schoenholz, and others; for radium rays by Zurhelle and Reisner, and for grenz rays by Kalz and Samek.

(a) *The first erythema*, occuring often within a few hours after irradiation, was designated by Holzknecht and Köhler (1903) as "the early erythema" or "the prereaction." Although widely used, these terms are not quite accurate. Since the latent period preceding the erythema, as is true of other ray effects, depends largely on the dose used, and may be prolonged for days when fractional irradiation with small single doses is applied, we prefer the designation "first erythema," indicating that further similar phenomena may follow.

The first erythema, which lasts from a few hours to a few days (two to four), reflects exactly the effect of rays on the capillaries. It is preceded, as a rule, by a narrowing of these vessels, followed by dilatation associated with a slight elongation, as described above. With larger doses, the accompanying hyperemia is manifested by an increasingly pronounced bluish color, indicating that the blood takes on more and more of a venous character as a result of the slowing of the circulation. The temperature of the skin as a rule is unchanged. The symptoms mentioned lead to the conclusion that the first erythema is venous or passive and not arterial or active in character. Neither mechanical compression of the arteries nor their constriction by means of adrenalin or cold is capable of preventing or suppressing the appearance of this first erythema. Hyperemic procedures are likewise of no effect. The responsibility for the first erythema is thus shown to rest solely upon the capillaries. In other words, it represents the primary effect of the rays on the capillaries. Because of the superficial situation of the latter in the skin the quality of rays does not influence the degree of the first erythema; it is of equal intensity after the softest grenz and the hardest radium rays. The reason is that any bundle of rays contains those which are absorbed in the superficially located capillaries. The first erythema is also largely independent of the dose applied, beyond a certain minimum, obviously because there is a limit to the possible dilatation of the capillaries.

(b) *The second erythema* results from the primary effect of the rays on the arteries. While, as has been stated, rays produce in the capillaries a temporary narrowing of the lumen followed by dilatation, the only effect produced in the arteries is narrowing. It has now to be added that with the same dose a narrowing effect of equal degree will be reached much later in the arteries than in the capillaries, for while the lumen of the average capillary measures about 0.08 μ, that of the smallest artery with a complete muscular coat is about 60 μ (Maximow, Bailey, and others). Thus when a so-called erythema dose is given, the strongest possible constrictor effect is reached in the capillaries in two to six hours; in the arteries eight to fourteen days may be required. As a result of the narrowing of the arteries, the blood flow is diminished and the delivery of oxygen to all tissues supplied by the affected vessels is decreased. From the experiments of Landis it appears that when an artery is ligated, even for a few minutes, the capillaries display an increased permeability, an effect similar to that seen in irradiated cells. This suggests that with attendant diminution of the oxygen supply a process of disintegration is induced which may be conceived as analogous to that encountered after radiation. Thus the molecules of the proteins are altered, the ratio between the

albumins and globulins is changed, the osmotic pressure rises, and eventually the cell swells. The swelling of the capillary endothelium leads by necessity to a narrowing of the lumen of short duration, followed by a more prolonged period of dilatation. Subsequently an increased amount of blood will flow in the dilated capillaries, giving rise to an erythema. This is in accordance with the experiments of Ricker, which are described by Boyd as follows: "Ricker found experimentally that strong contraction of an artery is followed by dilatation of its capillaries. When the arterial spasm passes off, blood flows in and diapedesis occurs through the walls of the dilated vessels." The erythema will last until, in the course of the hyperemia, the oxygen deficiency is overcome. Subsequently the swelling of the endothelial cells regresses, the hyperemia vanishes, and the capillaries regain their normal lumen. Thus, after a duration of from four to eight days or more, the second erythema will have gone.

In accordance with the different origin of the two erythemas the first is of a more passive character, and the second more in the nature of a so-called reactive hyperemia, in that the blood appears accelerated and the color brighter, at least in the beginning.

The narrowing of the arteries in the second erythema can be demonstrated, according to Siedamgrotzky, by injecting a drop of adrenalin (concentration 1 : 1 billion) intracutaneously. The arteries contract and, owing to the reduced supply of oxygen, the capillaries show an increased permeability so that a wheal is formed. Normally such a wheal disappears after ten to twenty minutes, but after irradiation it persists for a much longer time and spreads over a larger area. This is an indication that the irradiated arteries react more strongly than normal to adrenalin, obviously because their lumina are narrower than those of non-irradiated vessels.

The second erythema can be suppressed, or at least markedly delayed or weakened, by compression or by cold or adrenalin.

A dose usually leading to an erythema will prove ineffective or less effective if the above-mentioned measures are used. Conversely heat applied before or during irradiation will produce an erythema of deeper color and longer duration.

In contrast to the first erythema, the intensity of the second erythema follows, within wide limits, the increase in dose, apparently because with the augmentation of the dose the narrowing of the arteries increases, and with this the degree of the subsequent reactive hyperemia in the affected capillaries. It is for this reason that Wintz rejected the first erythema and recognized only the second erythema as the basis for the biological determination of the dose applied.

In respect to the quality of rays, also, there is a difference between the first and second erythema. While the quality of rays is of no noticeable influence on the first erythema, the second erythema requires about 25 per cent more ray energy when hard rays are used than with soft rays (Wintz, Flaskamp, etc.). With this a prolongation of the latent period is associated. The reason is that the more penetrating the rays used, the more of the deeper arteries are narrowed. This causes, naturally, an erythema of less intensity and delayed appearance.

The relationship between the state of the arteries and the intensity of the second erythema appears furthermore from the following observations. When the afferent arteries appear narrowed, the second erythema is less pronounced. This might be the reason why in Raynaud's disease or in hypertonia, where the small arteries are spastically contracted, the erythema is usually less intense. Differences in the intensity of the skin erythema exist, also, in different regions of the body subjected to irradiation. The erythema appears more pronounced in those regions where the underlying tissue is loose, as in the axilla or the inguinal region, and less pronounced where the underlying tissue is muscle, as in the face, or bone, as in the thorax. In the latter cases the small ar-

teries are obviously compressed and the hyperemic effect on the capillaries is consequently less.

The contrary may be seen when the afferent small arteries are dilated as a result of an inflammatory condition and thus are better filled with blood. In this condition the capillaries are more abundantly supplied with blood so that the erythema and all other vascular phenomena are more pronounced and may be produced by a smaller dose.

(c) *The third erythema* is the result of the ray effect on the veins. Like the arteries, the veins are composed of endothelium plus

become visible. It was Miescher who first proved that, given a certain dose, the appearance of the third erythema is as characteristic a radiation effect as the first and second one. Like the first and second erythema it is restricted to the irradiated field, so that in this case, also, merely the minute vessels are involved. The characteristic features of the third erythema may be described as follows:

1. There is no period of narrowing of the capillaries, but the dilatation sets in immediately and increases steadily.

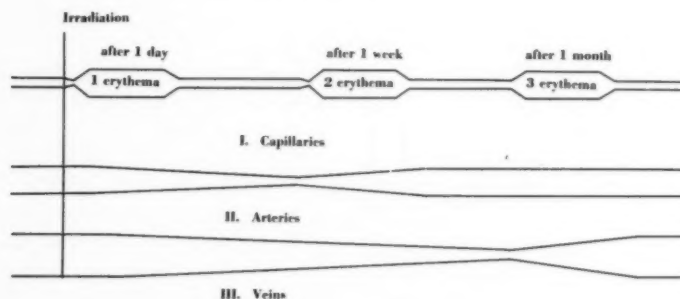2. The color is particularly intense, of bluish tint.

Fig. 3.   The three erythema waves

muscle and connective tissue, and narrowing of the lumen is the only possible radiation effect. The walls of the veins, however, are thinner, and their lumen is wider than that of the arteries, reaching as much as 200 μ (Bailey and others). It is evident, therefore, that if the maximum narrowing of the lumen which the given dose may produce is obtained in the arteries within one week, four weeks or even more may be required for an equal effect in the corresponding vein. The second erythema will have come and gone before the narrowing of the lumen of the veins makes its appearance. The sequelae of this event are clear: a prestenotic dilatation of the capillaries and venules situated behind the narrowed veins will result. This will lead to a slowing of the bloodstream so that the vessels become hyperemic and at last, about four to six weeks from the time of radiation, the third erythema of the irradiated area will

3. It cannot be suppressed either by adrenalin or by compression or cold.

The quantity of rays has a definite bearing on the third erythema. On account of their larger lumina the veins require a higher dose before they are narrowed to an extent causing a prestenotic dilatation of the afferent capillaries.

The quality of rays seems to have no noticeable effect on the appearance of the third erythema. It can be produced by equal doses of soft and hard x-rays, by grenz and radium rays. This is because the veins lie in a superficial layer of the skin. Once they become swollen and constricted, the narrowing of those more deeply situated has no further influence on the dilatation of the capillaries.

Although the majority of radiologists recognize only three erythemas, a few maintain that there are four and even more. This appears, however, to be due to

errors in interpretation. Kalz, for example, apparently fails to recognize the fact that not all cells react to irradiation at the same time and that the response of some of the capillaries after twenty-four to forty-eight hours is still a part of the first erythema. Others interpret as additional erythemas what are actually only variations in intensity of a single erythema at different times of the day (described by Glocker, Hayer, and Jüngling), or as a result of slight irritation, as by patting or rubbing. If all such sources of possible misinterpretation are eliminated, three and only three erythemas can be recognized.

Figure 3 shows graphically the sequence of changes in the blood vessels in the course of the formation of the ray erthemya.

EDEMA

The effect of radiation on cells manifests itself, as has been pointed out, by the disintegration of protein molecules of larger size into those of smaller size. The result of this transformation is an increase in osmotic pressure within the cells, leading to imbibition of fluid from the neighborhood and swelling of the cells.

Endothelial cells prove no exception, and participate in this same general process. Owing to their special function, however, further effects occur which are peculiar to cells of this type. In all other cells, the entire volume of fluid entering remains within the cell. In the case of endothelial cells, a part of the fluid imbibed, physiologically, is allowed to escape into the surrounding tissues. This singular effect is due to the fact that the endothelium lining the blood vessels is the only tissue of the body which is under the constant stress of the *blood pressure*. The pressure of the blood on the internal surface of the endothelium represents a force acting from without the cells while the osmotic pressure acts from within. As a consequence of this summation of forces, a part of the fluid which enters the cell by osmosis leaves again under the pushing force of the blood pressure.

Normally, the blood pressure at the arterial end of the capillaries (32 mm.) is considerably higher than at the venous end (12 mm.). The osmotic pressure of the surrounding tissues amounts to 25 mm., thus being lower than the blood pressure at the arterial end and higher at the venous end of the capillaries. As a consequence, a balance is maintained between the substances delivered to the tissues (salts, O_2, etc.) and the substances returning to the blood stream (CO_2, products of cell metabolism). Similarly, a balance exists between entering and returning water. In the state of rest, water leaves the capillaries at the arterial end and re-enters at the venous end.

Under the influence of radiation this relationship is modified remarkably. There is an increase in the permeability of the vessel walls and consequently an increased migration of water from blood to tissues, as can be demonstrated by the injection of a vital stain, such as trypan blue, into the blood. Following irradiation, the dye is found in the irradiated tissues outside the blood vessels. The increased migration of water from blood to tissues is not counterbalanced by an equally strong passage in the other direction, and this disproportion gives rise to *post-radiation edema*.

The principal reason for the increased migration from blood to tissues is not, however, the elevation of the blood pressure within the capillaries, as is indicated by the fact that the post-radiation edema may occur before there has been a noticeable dilatation of capillaries. This is also suggested by the fact that the edema depends largely on the structure and radiosensitivity of the tissues surrounding the irradiated vessels. It is, for example, much more pronounced after irradiation of a lymphoblastoma than after similar treatment of a squamous-cell carcinoma. In other words, like cellular swelling, the edema is more marked the greater the radiosensitivity of the irradiated cells. *This suggests that one important mechanism responsible for the post-radiation edema is the increase in osmotic pressure outside the ves-*

sels, due to the decomposition of intracellular proteins. While it is true that the rays act, also, on the cells suspended in the blood stream, the vast majority of these cells are the highly radioresistant red corpuscles. Less protein is decomposed, therefore, within the vessels than without. It is well established that the blood of irradiated persons shows an albumin-globulin ratio altered in the direction of increased globulins (Knipping and Kowitz, Herzfeld and Schinz, etc.). If, however, a protein solution is irradiated *in vitro*, the ratio is altered in favor of the albumins (Knipping and Kowitz). This difference is accounted for by the increased permeability of the capillary walls induced by radiation and the fact that the albumins, being of smaller molecular size, pass more easily through these walls along with the edema fluid. Thus the post-radiation edema fluid, as a rule, contains proteins in varying concentrations. Besides this, there are regularly found within it varying numbers of lymphocytes, even at a very early stage. This will be described in greater detail in the discussion of "Inflammation."

The anatomical character of the connective tissue is also influential in determining the degree of edema. The looser the connective tissue, other things being equal, the more pronounced is the edema, and conversely, the firmer the connective tissue the less marked the edema. Thus, in the tissue of the axilla or neck, the edema of radiation is greater than in the tissue about bone or fat. In short, the more compressible the connective tissue surrounding the blood vessels, the more pronounced is the post-radiation edema. Another factor is the rapidity of resorption of the fluid. When resorption is restrained, as for example by the capsule surrounding a salivary gland, edema may progress to a very marked degree. The rôle of the lymphatics in the resorption of edema fluid will be discussed in greater detail under another heading.

As to the relationship between the edema and erythema, one may say that in general there is a parallelism in intensity between the two phenomena. Thus there are three waves of edema, just as there are three waves of erythema, although clinically they are less distinctly demarcated. We have to assume that the edema associated with the first erythema persists and is augmented by the following waves as a result of the subsequent dilatation of the capillaries. On the other hand, edema may develop even in the absence of erythema. In the skin, edema may become evident after a single dose leading to a temporary epilation. This is because the cells of the hair follicles are so highly sensitive that even a small dose can initiate the cycle of intracellular protein disintegration, increased osmotic pressure, and edema. Thus a dose leading to a temporary epilation may be considered the lowest dose capable of producing edema after irradiation of normal tissues. In pathological tissues, even smaller doses, such as those used in the treatment of inflammatory conditions, may give rise to edema.

It follows from this description that an essential difference exists between the factors leading to a ray edema and ray erythema. While the erythema represents a radiation effect on the vessels only, the edema is the result of the combined effect on the vessels and the perivascular tissues. Consequently, while the intensity of the erythema depends only on the dose applied, the intensity of the edema depends also on the sensitivity of the irradiated tissues.

Although an edema may be produced even with a suberythema dose, it is undoubtedly hastened in proportion to the dilatation of the vessels, since the more swollen and distended the cells, the greater becomes the permeability of their walls. This is well illustrated by observations of Landis, referred to above, showing that, after restitution of constricted arteries to normal caliber, the capillaries dilate and their permeability increases in equal measure. This applies also to corpuscular elements, as appears from an experiment of Herzog, showing that India ink injected into the blood may be found in the walls of the exposed capillaries of the tongue.

Thus, while edema may occur without erythema, erythema is regularly associated with edema. The more pronounced the erythema, the more important does the rôle of vascular insult become in the formation of edema as compared to injury to perivascular tissues.

The fluid passes through the capillary walls and pervades the perivascular tissues progressively: stratum papillare, stratum reticulare, finally subcutaneous fat tissue. This leads to the separation of structures normally adjacent to each other. Thus the collagenous fibers become separated, the epidermis becomes separated from the corium, the hair from the follicles. This accounts also for the development of intra-epidermal vesicles.

If the permeability of the capillaries is increased on a large scale, an extensive loss of fluid takes place and increased concentration of the blood results. This phenomenon of "hemoconcentration" is, according to Moon, the first link of a chain of processes leading in the end to "radiation sickness." Essentially this syndrome is identical with shock of any other origin. The symptoms are general weakness, nausea or vomiting, acceleration of the pulse, decrease of blood pressure, oliguria, and diarrhea. In the blood there is a decrease of chlorides, of bicarbonate, and cholesterol, and on the other hand increase of the non-protein nitrogen and the hydrogen ion concentration. The ultimate cause of these changes is the increased permeability of the capillaries as a result of their dilatation and the increased osmotic pressure in their neighborhood. The first is the result of the changes produced by the rays in the vessels while the latter results from the changes brought about in the irradiated tissues. The observations of Whipple, Hall, and Warren, as well as those of Moon, Kornblum and Morgan on animals with evidence of radiation sickness following irradiation of the abdomen have revealed congestion of the capillaries with perivascular edema and hemorrhage, and degenerative and necrotic changes in various abdominal organs, particularly in the small intestines. These experimental observations are in full harmony with the clinical experience showing that the radiation sickness is most pronounced after irradiation of the abdomen. The numerous lymph follicles in the small intestines are highly radiosensitive and their capillaries are characterized by a permeability far exceeding that of all other organs. Besides the region of the body, the size of the irradiation field and the dose also play an important part in the causation of radiation sickness.

Another important sequel of the post-radiation edema is opacity of the lens occurring after irradiation of the eye. If a dose causing an erythema in the skin is given to the eye in one sitting, a swelling of the endothelial cells of the lens results, as in the case of the capillaries. In contrast to the capillaries, however, which are surrounded by solid tissue, the lens is suspended in an aqueous medium. Furthermore, while the capillaries contain a fluid, in the lens the endothelial cells are differentiated to fibers, forming a solid center. Hence, irradiation, which causes an increase of the osmotic pressure *outside* the capillaries, produces an increased osmotic pressure *inside* the lens. Fluid from the neighboring aqueous medium is attracted and the fibers of the endothelial cells swell until eventually the lens becomes opaque. This mode of action is in full accord with animal experiments of Hess (1887), who showed that after artificial damage to its capsule, fluid entered the lens and the fibers became swollen and opaque.

A large number of important radiobiological phenomena, apparently of quite different character, thus prove to be based on the same principle: the increased permeability of the capillaries.

Quite different is the course of the edema caused by irradiation of the endothelium of the *arteries and veins*. Only when a larger dose is given, will there be a permeation of fluid through the endothelium of arteries and veins. Even when this occurs, the muscle and connective tissue offer strong resistance to the passage of fluid. Hence

the fluid spreads subendothelially and causes elevation of the endothelium. The event contributes, along with swelling of endothelial cells, to the narrowing of the arterial and venous lumina with all the attendant sequelae. Spreading in the subendothelial region, the fluid may also separate the fibers of the connective tissues. Furthermore, it supplies the fluid which is attracted by the fibroblasts and leads to the swelling of these cells. This gives rise, as will be discussed in greater detail later, to proliferation of these cells, leading eventually to a greater or less degree of fibrosis of the intima.

(*To be continued*)

A Simple Film-Drying Shelf for the Dark Room[1]

HYMAN I. TEPERSON, M.D.

Brooklyn, N. Y.

IN MOST laboratories wet x-ray films are dried by suspending the developing frame or hanger from a rack attached to the wall of the dark room. One end of the top bar of the hanger is inserted in the rack in cantilever fashion. A slight angulation

We have obviated most of these disadvantages by drying our wet films on a shelf, resting the hanger on the shelf with the heavy part of the frame on the bottom: a reversal of the usual drying position. The shelf is placed on the wall of the dark room
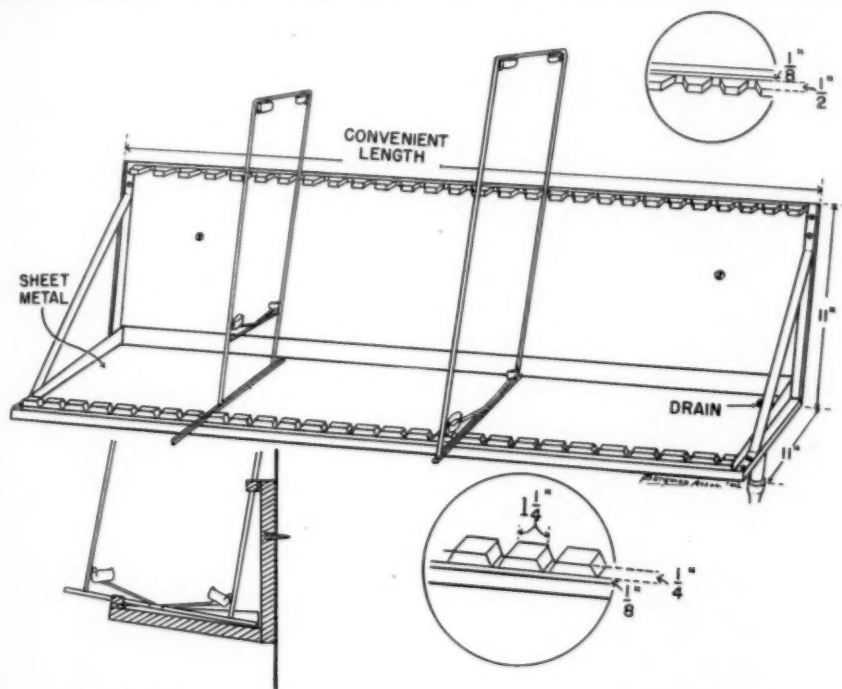

Fig. 1. Sketch of film-drying shelf in perspective. Insets show details of upper and lower notched moldings and also side view of shelf and relative position of film hanger. The entire shelf is hung or attached to the wall with a slight tilt to the drain side.

facilitates the draining of the water to the most dependent corner of the hanger, from which it drops into a basin, tank, or onto the floor. Even if one has an electric film drier, the films have to be carried from the developing tank to the drier, leaving a wet trail on the floor. Often films have to be viewed before they are dry, and in the handling, residual drops of water, adherent to the heavy frame above, are disturbed and drop to the films, spotting them.

about two feet above the tank, which puts it within easy reach of the technician. Films taken from the washing compartment of the tank are immediately placed on the shelf above. This shelf is constructed with a slight pitch toward the rear, and the entire shelf is hung with a slight tilt to one end, thus facilitating drainage. A small drain is placed at one end and back of the shelf. Dripping water is carried away from the drain to the waste compartment of the tank below by a small

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rubber connecting tube. On damp days, drying of films can be expedited by a breeze from a very small fan suspended from the ceiling above the shelf.

This drying shelf is inexpensive and easily constructed. It is made of two boards, 11 inches wide and 3/4 of an inch thick, the length depending upon the available wall space. The two boards are joined at an angle of 85 degrees. End pieces or angle irons reinforce the boards at the ends. The horizontal board, which forms the shelf, is lined or covered with a metal sheeting of galvanized iron or copper, which is continued for one inch along the length of the upright board which forms the back. A small hole, 1/2 inch in diameter, is drilled through one end and back of the horizontal board to accommodate the drain pipe. A rubber tube is used to connect this drain pipe to the waste compartment of the tank. To maintain the film hangers in position while drying, a molding 1/2 inch by 1/2 inch is placed along the free edge of each board. Notches 3/16 inch wide and 3/8 inch deep are cut into this molding at intervals of 1 1/2 inches. The bottom of the notches will thus be 1/8 inch above the surface of the shelf, so that a small air space will always be present between the film hanger and the shelf. This helps drainage and keeps the frame dry.

SUMMARY

A new film-drying shelf is described. Its use will make a clean place of an untidy dark room.

744 Eastern Parkway, Brooklyn, N. Y.

CASE REPORTS

Calcified Ependymoblastoma of the Fourth Ventricle in a Four-Year-Old Girl: Roentgen Demonstration[1]

EDWIN BOLDREY, M.D., and EARL R. MILLER, M.D.
San Francisco, Calif.

CALCIFICATION is rare in the gliomas found in children under four years of age. Rarer still is the demonstration of

these unusual features, this single instance is presented as a case study.

J. D., a white female, 3 years and 7 months of age, was first admitted to the Neurosurgical Service at the University of California Hospital on Sept. 6, 1939. Beginning two and a half months before entry, without previous relevant illness, she had had periodic nausea, vomiting, and anorexia.

At first the presence of a tumor of the posterior fossa was not recognized. When the child was seen

Fig. 1. Calcified ependymoblastoma: antero-posterior roentgenogram showing calcification in the midline.

calcium by roentgenography; this is especially true when the calcified lesion lies in the posterior fossa. Because it possesses

on Jan. 6, 1940, spasticity, ataxia, cracked-pot percussion note, and bilateral papilledema were present. Roentgenograms of the skull on Jan. 8, 1940 (Figs. 1 and 2) showed a calcified midline lesion in the posterior fossa.

For some time, children admitted to this hospital with findings suggestive of tumor of the posterior

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fossa have been given a course of roentgen therapy as a therapeutic test for a radiosensitive neoplasm. It was felt that this therapy should be administered first even in a situation such as will be described, in which the lesion was known to contain radiopaque material, probably calcium. Accordingly the child received 1900 r through each of two ports in the lateral occipital region. Temporary improvement followed, despite an intercurrent mastoiditis. By September 1940, however, it was obvious that a craniotomy would be necessary.

The cells were uniform with regular oval-round nuclei and long coarse processes characteristically lined up and attached. The calcium was identified by means of stained preparations, including von Kossa's technic.

In 100 cases of intracranial tumor in children Bailey, Buchanan, and Bucy (1) found only 7 ependymomas, 5 of which occurred in children less than four years of age. Other cases of ependymoma in this age group have been re-

Fig. 2. Calcified ependymoblastoma: right lateral view, showing calcification to be in the posterior fossa.

A firm grayish red growth was removed from the fourth ventricle. This tumor extended from the aqueduct of Sylvius, through the fourth ventricle and foramen of Magendie, to the level of the lamina of the second cervical vertebra. Its only attachment was in the midline near the calamus scriptorius. In separating this attachment it was necessary to clip one large vessel. This initiated retrograde thrombosis, which resulted in extensive medullary necrosis and death on the second day.

Histopathologically, the tumor was a calcified ependymoblastoma with extensive degeneration.

ported by Mackay (2), Gross (3), Bailey and Cushing (4), and Fincher and Coon (5); 7 of the 9 were found in males. Only one of these authors (Mackay) mentioned the demonstration of calcium by histologic study; we assume that in the other cases none was found. This is not surprising because, although ependymomas tend to calcify, the generally accepted theories concerning the etiology of calcium deposits include time factors not to be ignored. In one of the more recent studies of calcifica-

tion, Eaton, Camp, and Love (6) reiterated the hypothesis generally accepted for at least three decades: "The pathological basis [for calcification] is one of colloid deposit . . . with subsequent calcification of the deposit." They subscribed to Meyer's hypothesis (7) that colloids may change so that they behave as gels, which in turn have an affinity for calcium salts. If these premises are accepted, it is evident that time is necessary for growth of the tumor, its degeneration, and replacement by colloid, and for the accumulation of calcium. Consequently the presence of these salts in tumors found in young children becomes worthy of note.

Most remarkable of all is the radiographic demonstration of this deposit. Considerably more calcium is required to throw a recognizable shadow on the x-ray film than to be demonstrated under the microscope. In addition, because of anatomical barriers, calcification in the posterior fossa is particularly difficult to discover by roentgenography. Pancoast, Pendergrass, and Schaeffer (8) wrote that they had never seen it there in a glioma, and others have noted its demonstration as unusual.

In Mackay's case, the shadow was visible on the x-ray film, but histologic study of this tumor showed that it contained bone. We found no other instance in which the patient was under four years of age.

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EDITORIAL

Howard P. Doub, M.D., Editor

John D. Camp, M.D., Associate Editor

Mass Chest Surveys

It is generally conceded that roentgen study of the lungs has a degree of accuracy in excluding pulmonary tuberculosis that leaves very little to be desired. Its reliability and ease of application have led to numerous roentgen surveys on a greater or less scale for the detection of previously undiscovered "silent lesions" in the general population. With the entrance of great numbers of men into the military and naval services of our country the subject has become increasingly important.

When it is realized that pulmonary tuberculosis in the soldiers of the World War No. 1 has already cost the government well over a billion dollars, with an average expenditure per case of $10,000 to $15,000, it is readily apparent that in the present emergency the most exact method of diagnosis possible must be employed to exclude from the armed forces every possible case of the disease. In addition to its accuracy, the method should be easy of application and as low in cost as possible, consistent with exactness.

Several roentgen methods are available for mass radiography of the chest: (1) the conventional method with full-size roentgenograms on sensitized film; (2) the use of sensitized paper instead of films; (3) fluoroscopy; (4) fluorography, with reduced images of several sizes. Each of these methods has certain advantages and disadvantages and each has its adherents.

(1) *Full-Size Roentgenograms on Film:* This method is the standard by which all other methods are assessed and is generally acknowledged to be the most accurate when used stereoscopically. It has a high degree of accuracy, also, when single films are used, Richards (8) having shown that

out of 328,325 such examinations on Canadian recruits for the military service only 16, or 0.004 per cent, showed a clearly negative roentgen picture and later developed clinical pulmonary tuberculosis in service. In addition there were 11 cases, or 0.003 per cent, in which the film showed evidence of tuberculosis which was overlooked by the roentgenologist. This latter source of error, insignificant as it is, can be attributed to fatigue on the part of the reader, as there was no disagreement as to the presence of the disease when the films were subsequently reviewed.

Richards believes that stereoscopic films exceed single films in accuracy by about 5 per cent. Not only is this true of the recognition of early or minimal disease, but fuller and more accurate information is provided about all other types of lesions.

The chief disadvantages of the 14 × 17-in. film are its cost and the space required for filing. Another objection to the method is its relative slowness in handling patients, but this objection could be eliminated by technical changes.

(2) *Full-Size Roentgenograms on Sensitized Paper:* Those who advocate this method do so on the basis of decreased cost and rapidity of handling of patients because of the use of paper in rolls. The only saving in cost, however, is the difference between the price of the paper and that of the film, as the other costs of maintaining a roentgen department are essentially the same in the two cases. Many authors have not considered fixed overhead costs in their estimates of the savings to be expected. None of the advocates of sensitized paper claims that it is as accurate for the detection of minimal lesions as is film. Experi-

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enced roentgenologists have felt that there is an advantage in viewing film by transmitted light over viewing paper by reflected light.

(*3*) *Fluoroscopy:* In the hands of a trained observer fluoroscopy is an inexpensive and rapid method of discovering well developed pulmonary and cardiac lesions. For early minimal lesions it is not as accurate as films. It has the added disadvantage that there is no permanent record for others to review.

Reid (7) believes fluoroscopy to be approximately as accurate as the single flat film. In 1,035 supposedly healthy persons examined both by roentgenoscopy and roentgenography, only 2 cases of tuberculosis of clinical significance were missed by the fluoroscopic examination. Ellman (3) states that in examining 3,229 persons by fluoroscopy and films he determined the accuracy of fluoroscopy to be 94 per cent of that shown by the films. It is only fair to state, however, that other reports do not claim so high an accuracy for fluoroscopic studies. The physical risk to the observer, the lack of a permanent record, and the inaccuracy of the method are not likely to recommend it to the average roentgenologist for mass examination of the lungs.

(*4*) *Fluorography:* This method employs a photograph of the screen image on a small film, usually measuring either 4 × 5 inches or 35 mm. In a recent review Christie (1) summarizes the advantages and disadvantages of the two fluorographic methods as follows:

"(*1*) *4 × 5 Inch Film. Advantages:* Relatively low cost (approximately one-tenth that of 14 × 17 in. film). Speed of operation about 60 per hour. Readable without enlargement. Low storage requirement. May be filed without change with the patient's record.

"*Disadvantages:* Cost of original equipment for photography is high and is in addition to the roentgen-ray equipment which must be capable of at least 200 ma. output.

"(*2*) *35 Mm. Film. Advantages:* Minimal expense (one-fiftieth that of 14 × 17 in. film). High speed of operation, about 150 per hour. Ease and convenience of storage. Photographic unit available in large number and not expensive.

"*Disadvantages:* Projection or magnification is required for reading the film. Less convenient than the 4 × 5 in. film for filing with patient's record."

The accuracy of these methods has been the subject of various studies in which the results were checked against those obtained with 14 × 17-in. films. Potter, Douglas, and Birkelo (6), in a study of 1,610 persons with 4 × 5-in. films, discovered 271 cases of tuberculosis with an error of 2.6 per cent. Plunkett (5) reports the results of a study of 1,000 persons in which 62 cases of tuberculosis were found by the 14 × 17-in. films. Thirty were in the minimal stage. None of the moderately or far advanced cases were missed in the small films, but 3.4 per cent of the minimal cases were missed on the 29 available 4 × 5-in. films, and 17.4 per cent on the 23 available 35-mm. films.

Most authors, in advocating one or the other of these methods, have laid stress on the great saving accruing from the use of the smaller films but have almost completely ignored the relation this bears to the total cost of the examination. Gough (4), in his detailed report of a study made in Sydney, Australia, takes into account the original cost, depreciation, and replacement of parts of apparatus, the materials used, rent, and lay help. He reports the cost of the examination, when 5,000 cases per annum were examined, to be 11.16 shillings when the 14 × 17-in. films were used; 7.30 shillings when the 4 × 5-in. films were used, and 6.82 shillings when the 35-mm. films were used. If, however, 100,000 cases per annum are used as a basis for comparison, the cost differential between the large films and fluorographic examinations is much more marked. With this number of cases the cost per case was 5.61 shillings when 14 × 17-in. films were used, 1.37 shillings when 4 × 5-in. films were used, and 1.19 shillings when 35-mm. films were used. It is obvious from this study that the cost differential is not important unless large numbers of cases are being studied.

On another page in this issue of RADIOLOGY Major de Lorimier presents an excellent

analysis of the factors which led to the official adoption by the U. S. Army of the stereoscopic method using 4 × 5-in. films. He clearly shows by comparison the saving in cost, filing space, fatigue of film reader, etc., obtained by the use of 4 × 5-in. films.

It would appear that the choice of method for mass radiography of the chest will depend somewhat on the objects to be attained and the available funds. If one wishes a general survey at a low cost in order to pick up more obvious lesions, and is reconciled to a percentage of error, several methods are available. Fluoroscopy is the cheapest but is dangerous to the operator and involves a considerable percentage of error depending upon the skill of the observer. The 35-mm. single film and 4 × 5-in. single film are justly popular and have a considerable degree of accuracy. Sensitized paper should be mentioned here but is more expensive than the others and no more accurate.

If it is essential that the highest percentage of minimal lesions be recognized, then stereoscopic images should be employed. Minimal lesions missed on single films are often those which are obscured by bony structures. Most writers rate 14 × 17-in

stereoscopic films as the most accurate method. Stereoscopic fluorographs employing 4 × 5-in. films rate a close second; stereoscopic paper images and 35-mm. fluorographs should also be considered. These have many advocates but do not deserve as high a rating as the first two. As a public health measure in discovering and isolating cases of tuberculosis, this is a matter of great importance.

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RESOLUTION

Whereas: The Radiological Society of North America is the largest special organization of Radiologists in the United States, and

Whereas: The Radiological Society of North America recognizes its obligation to the War Department in the present national emergency, and

Whereas: The Radiological Society of North America through its Board of Directors wishes to be of the utmost assistance to its membership and to radiology in medical military matters, and at the same time provide prompt unanimous action in such matters, and

Whereas: The American College of Radiology already has a Medical Military Committee functioning for radiology as a national organization.

Therefore be it resolved that it shall be the policy of the Board of Directors of the Radiological Society of North America to delegate matters of a medical military nature, as they may concern radiologists, to the Medical Military Committee of the American College of Radiology.

By direction of the Board of Directors of the Radiological Society of North America.

A. L. L. BELL, M.D., *Chairman*
D. S. CHILDS, M.D., *Secretary*

February 14, 1942
Chicago, Illinois

CONSERVATION OF SCHOLARLY JOURNALS

There was created in the last year, by the American Library Association, a Committee on Aid to Libraries in War Areas, headed by John R. Russell, librarian of the University of Rochester. This Committee is seeking the co-operation of American scholars and scientists in the solution of one of the problems facing it.

One of the most difficult tasks in library reconstruction after the first World War was that of completing foreign institutional sets of American scholarly, scientific, and technical periodicals. The attempt to avoid a duplication of that situation is now the concern of the Committee.

Many sets of journals will be broken by the financial inability of institutions to renew subscriptions. As far as possible they will be completed from a stock of periodicals being purchased by the Committee. Many more will have been broken through mail difficulties and loss of shipments, while still other sets will have disappeared in the destruction of libraries. The eventual demand is impossible to estimate, but requests received by the Committee already give evidence that it will be enormous.

With an imminent paper shortage attempts are being made to collect old periodicals for pulp. Fearing a possible reduction in the already limited supply of scholarly and scientific journals, the Committee hopes to enlist the co-operation of subscribers to RADIOLOGY in preventing the sacrifice of this type of material to the pulp demand. It is scarcely necessary to mention the appreciation of foreign institutions and scholars for such co-operation.

Questions concerning the project or concerning the value of particular periodicals to the project should be directed to Wayne M. Hartwell, Executive Assistant to the Committee on Aid to Libraries in War Areas, Rush Rhees Library, University of Rochester, Rochester, New York.

THE AMERICAN ROENTGEN RAY SOCIETY

The recently elected officers of the American Roentgen Ray Society are:

President: Dr. Ralph S. Bromer, Philadelphia, Pa.

First Vice-President: Dr. Frederick William O'Brien, Boston, Mass.

Second Vice-President: Dr. Fred J. Hodges, Ann Arbor, Mich.

Secretary: Dr. Harold Dabney Kerr, Iowa City, Iowa.

Treasurer: Dr. J. Bennett Edwards, Leonia, N. J.

Historian: Dr. Ramsay Spillman, New York City, N. Y.

THE AMERICAN SOCIETY OF X-RAY TECHNICIANS

The Seventeenth Annual Convention of The American Society of X-Ray Technicians will be held in Chicago, Ill., June 22–26, 1942, with the Congress Hotel as headquarters. The general chairman is Mabel M. Walsh, R.T., 6437 Kimbark Ave., Chicago.

In Memoriam

JACOB JOSHUA LEVY
1879–1942

Dr. Jacob J. Levy, of Syracuse, New York, died of leukemia on Feb. 22, 1942. Dr. Levy was born in Elmira, N. Y., in 1879, and was graduated from Syracuse University in 1900, being awarded his degree of Doctor of Medicine by that institution in 1903. He was Assistant Professor in Medicine at

the College of Medicine, Syracuse University, and Attending Physiotherapist at the University Hospital and the Syracuse Free Dispensary. He was a member of the American Roentgen Ray Society, the Syracuse Academy of Medicine, the Radiological Society of North America, and the New York State Medical Society.

CASSIE BELL ROSE-THATCHER
1883–1942

Word has recently been received of the death of Dr. Cassie Bell Rose-Thatcher, head of the X-ray Department of the Presbyterian Hospital, Chicago, for nearly twenty years, and more recently director of the X-ray Department at Porter Sanitarium and Hospital, Denver, and Boulder Sanitarium, Boulder, Colo. Dr. Rose-Thatcher was born in Columbus, Kansas, was graduated from the University of Oklahoma in 1911 and from the Rush Medical School, Chicago, in 1915. She was a member of the Radiological Society of North America, the American Roentgen Ray Society, and local medical societies in Chicago and in Colorado.

Books Received

Books received are acknowledged under this heading, and such notice may be regarded as recognition of the courtesy of the sender. Reviews will be published in the interest of our readers and as space permits.

ROENTGEN TREATMENT OF INFECTIONS. By JAMES F. KELLY, M.D., Professor and Director of the Department of Radiology, Creighton University School of Medicine; Attending Radiologist, Creighton Memorial St. Joseph's Hospital, and D. ARNOLD DOWELL, M.D., Assistant Professor of Radiology, Creighton University School of Medicine. A volume of 432 pages with 122 illustrations. Published by The Year Book Publishers, Inc., Chicago, 1942. Price $6.00.

Book Review

THE TREATMENT OF BURNS. By HENRY N. HARKINS, M.S., M.D., Ph.D., F.A.C.S., Associate Surgeon, Henry Ford Hospital, Detroit; formerly Instructor in Surgery, University of Chicago; John Simon Guggenheim Memorial Fellow in Surgery, 1938–1939. A volume of 457 pages with 120 figures. Published by Charles C. Thomas, Springfield, 1942. Price $6.50.

In this book the author has collected most of the worth-while information on the treatment of burns, in addition to reviewing the subject of burns from the standpoint of pathology, chemical changes, blood concentration etc. All of the important experimental work is included and the various theories regarding shock and other pertinent matters are covered.

Dr. Harkins has spent much time in both experimental and clinical studies not only in this country but also abroad, where he had the opportunity of observing various forms of treatment at first hand. Thus he speaks from an extensive and well rounded experience.

Each type of treatment is presented in detail, without any obvious effort to make it appear at an advantage over the others, and illustrations are plentiful. The book is thus a very useful one and should have a wide and favorable reception. A comprehensive bibliography makes it of the greatest value as a reference work.

Editor's Note.—Will secretaries of societies please co-operate by sending information to Howard P. Doub, M.D., Editor, Henry Ford Hospital, Detroit, Mich.

UNITED STATES

Radiological Society of North America.—*Secretary*, D. S. Childs, M.D., 607 Medical Arts Building, Syracuse, N. Y.

American Roentgen Ray Society.—*Secretary*, Harold Dabney Kerr, M.D., Iowa City, Iowa.

American College of Radiology.—*Secretary*, Mac F. Cahal, 540 N. Michigan Ave., Chicago, Ill. Annual Meeting, 1942, Atlantic City, N. J.

Section on Radiology, American Medical Association.—*Secretary*, J. T. Murphy, M.D., 421 Michigan St., Toledo, Ohio. Annual Meeting, 1942, Atlantic City, N. J.

ARKANSAS

Arkansas Radiological Society.—*Secretary-Treasurer*, J. S. Wilson, M.D., Monticello. Meets every three months and annually at meeting of State Medical Society.

CALIFORNIA

California Medical Association, Section on Radiology.—*Secretary*, Joseph D. Coate, M.D., 434 Thirtieth St., Oakland.

Los Angeles County Medical Association, Radiological Section.—*Secretary*, Donald R. Laing, M.D., 65 N. Madison Ave., Pasadena. Meets second Wednesday of each month at County Society Building.

Pacific Roentgen Society.—*Secretary-Treasurer*, L. Henry Garland, M.D., 450 Sutter St., San Francisco. Society meets annually during annual meeting of the California Medical Association.

San Francisco Radiological Society.—*Secretary*, J. Maurice Robinson, M.D., University of California Hospital. Meets monthly on third Thursday at 7:45 P.M., for the first six months at Toland Hall (University of California Medical School); second six months at Lane Hall (Stanford University School of Medicine).

COLORADO

Denver Radiological Club.—*Secretary*, Edward J. Meister, M.D., 366 Metropolitan Bldg. Meetings third Friday of each month at the Denver Athletic Club.

CONNECTICUT

Connecticut State Medical Society, Section on Radiology.—*Secretary-Treasurer*, Max Climan, M.D., 242 Trumbull St., Hartford. Meetings bimonthly, on second Thursday. Place of meeting selected by Secretary.

FLORIDA

Florida Radiological Society.—*Secretary-Treasurer*, Walter A. Weed, M.D., 204 Exchange Building, Orlando. Next meeting at annual meeting of State Medical Association, April 13–15, 1942, Palm Beach.

GEORGIA

Georgia Radiological Society.—*Secretary-Treasurer*, Robert C. Pendergrass, M.D., Prather Clinic Bldg., Americus. Meetings twice annually, in November and at the annual meeting of State Medical Association.

ILLINOIS

Chicago Roentgen Society.—*Secretary*, Chester J. Challenger, M.D., 3117 Logan Blvd. Meets at the Palmer House on the second Thursday of October, November, January, February, March, and April.

Illinois Radiological Society.—*Secretary-Treasurer*, William DeHollander, M.D., St. Johns' Hospital, Springfield. Meetings quarterly by announcement.

Illinois State Medical Society, Section on Radiology.—*Secretary*, Earl E. Barth, M.D., 303 E. Chicago Ave., Chicago.

INDIANA

The Indiana Roentgen Society.—*Secretary-Treasurer*, Harold C. Ochsner, M.D., Methodist Hospital, Indianapolis. Annual meeting in May.

IOWA

The Iowa X-ray Club.—Holds luncheon and business meeting during annual session of Iowa State Medical Society.

KENTUCKY

Kentucky Radiological Society.—*Secretary-Treasurer*, Joseph C. Bell, M.D., 402 Heyburn Bldg., Louisville. Meeting annually in Louisville, third Sunday afternoon in April.

LOUISIANA

Louisiana Radiological Society.—*Secretary-Treasurer*, Johnson R. Anderson, M.D., North Louisiana Sanitarium, Shreveport. Meets annually at same time as State Medical Society. Next meeting, New Orleans, April 1942.

Shreveport Radiological Club.—*Secretary-Treasurer*, W. R. Harwell, M.D. Meetings monthly on the second Wednesday, at the offices of the various members.

MARYLAND

Baltimore City Medical Society, Radiological Section.—*Secretary*, Walter L. Kilby, M.D., 101 W. Read St. Meetings are held the third Tuesday of each month.

MICHIGAN

Detroit X-ray and Radium Society.—*Secretary-Treasurer*, E. R. Witwer, M.D., Harper Hospital, Detroit. Meetings first Thursday of each month from October to May, inclusive, at Wayne County Medical Society club rooms, 4421 Woodward Ave., Detroit.

Michigan Association of Roentgenologists.—*Secretary-Treasurer*, E. M. Shebesta, M.D., 1429 David Whitney Bldg., Detroit. Meetings quarterly by announcement.

MINNESOTA

Minnesota Radiological Society.—*Secretary*, John P. Medelman, M.D., 572 Lowry Medical Arts Bldg., St. Paul. Meetings quarterly.

MISSOURI

The Kansas City Radiological Society.—*Secretary*, P. E. Hiebert, M.D., 907 North Seventh St. (Huron Bldg.), Kansas City, Kansas. Meetings last Thursday of each month.

The St. Louis Society of Radiologists.—*Secretary*, Wilbur K. Mueller, M.D., University Club Bldg. Meets on fourth Wednesday of October, January, March, and May, at a place designated by the president.

NEBRASKA

Nebraska Radiological Society.—*Secretary*, D. A. Dowell, M.D., 816 Medical Arts Bldg., Omaha. Meetings third Wednesday of each month at 6 P.M. in either Omaha or Lincoln.

NEW ENGLAND

New England Roentgen Ray Society (Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island).—*Secretary*, Hugh F. Hare, M.D., Lahey Clinic, Boston, Mass. Meets monthly on third Friday at Boston Medical Library.

NEW JERSEY

Radiological Society of New Jersey.—*Secretary*, H. J. Perlberg, M.D., Trust Co. of New Jersey Bldg., Jersey City. Meetings at Atlantic City at time of State Medical Society and midwinter in Newark as called by president.

NEW YORK

Associated Radiologists of New York, Inc.—*Secretary*, William J. Francis, M.D., 210 Fifth Ave., New York City. Regular meetings the first Monday evening of the month in March, May, October, and December.

Brooklyn Roentgen Ray Society.—*Secretary-Treasurer*, Leo Harrington, M.D., 880 Ocean Ave. Meetings held the fourth Tuesday of every month, October to April.

Buffalo Radiological Society.—*Secretary-Treasurer*, Joseph S. Gianfranceschi, M.D., 610 Niagara St. Meetings second Monday evening each month, October to May, inclusive.

Central New York Roentgen Ray Society.—*Secretary-Treasurer*, Carlton F. Potter, M.D., 425 Waverly Ave., Syracuse. Meetings are held in January, May, and October, as called by Executive Committee.

Long Island Radiological Society.—*Secretary*, Marcus Wiener, M.D., 1430 48th St., Brooklyn. Meetings fourth Thursday evening each month at Kings County Medical Bldg.

New York Roentgen Society.—*Secretary*, Paul C. Swenson, M.D., Presbyterian Hospital, New York. N. Y.

Rochester Roentgen-ray Society.—*Secretary*, S. C. Davidson, M.D., 277 Alexander St. Meetings at convenience of committee.

NORTH CAROLINA

Radiological Society of North Carolina.—*Secretary-Treasurer*, Major I. Fleming, M.D., 404 Falls Road, Rocky Mount. Meeting with State meeting in May, and meeting in October.

NORTH DAKOTA

North Dakota Radiological Society.—*Secretary*, L. A. Nash, M.D., St. John's Hospital, Fargo. Meetings by announcement.

OHIO

Ohio Radiological Society.—*Secretary*, J. E. McCarthy, M.D., Cincinnati. The next meeting will be held at the time and place of the annual meeting of the Ohio State Medical Association.

Cleveland Radiological Society.—*Secretary-Treasurer*, J. O. Newton, M.D., 13921 Terrace Road, East Cleveland. Meetings at 6:30 P.M. at the Mid-day Club, in the Union Commerce Bldg., on fourth Monday of each month from October to April, inclusive.

Radiological Society of the Academy of Medicine (Cincinnati Roentgenologists).—*Secretary-Treasurer*, Justin E. McCarthy, M.D., 707 Race St. Meetings held third Tuesday of each month.

PENNSYLVANIA

Pennsylvania Radiological Society.—*Secretary-Treasurer*, L. E. Wurster, M.D., 416 Pine St., Williamsport. The Society meets annually. Next meeting at Necho Allen Hotel, Pottsville, May 15-16, 1942.

The Philadelphia Roentgen Ray Society.—*Secretary*, Barton R. Young, M.D., Temple University Hospital, Philadelphia. Meetings held first Thursday of each month at 8:15 P.M., from October to May, in Thomson Hall, College of Physicians, 21 S. 22nd St., Philadelphia.

The Pittsburgh Roentgen Society.—*Secretary-Treasurer*, Harold W. Jacox, M.D., 4800 Friendship Ave., Pittsburgh, Pa. Meetings are held on the second Wednesday of each month at 4:30 P.M., from October to June, at the Pittsburgh Academy of Medicine, 322 N. Craig St.

ROCKY MOUNTAIN STATES

Rocky Mountain Radiological Society (North Dakota, South Dakota, Nebraska, Kansas, Texas, Wyoming, Montana, Colorado, Idaho, Utah, New Mexico).—*Secretary*, A. M. Popma, M.D., 220 North First St., Boise, Idaho.

SOUTH CAROLINA

South Carolina X-ray Society.—*Secretary-Treasurer*, Malcolm Mosteller, M.D., Columbia Hospital, Columbia. Meetings in Charleston on first Thursday in November, also at time and place of South Carolina State Medical Association.

TENNESSEE

Memphis Roentgen Club.—Chairmanship rotates monthly in alphabetical order. Meetings second Tuesday of each month at University Center.

Tennessee Radiological Society.—*Secretary-Treasurer*, Franklin B. Bogart, M.D., 311 Medical Arts Bldg., Chattanooga. Meeting annually with State Medical Society in April.

TEXAS

Texas Radiological Society.—*Secretary-Treasurer*, L. W. Baird, M.D., Scott and White Hospital, Temple.

VIRGINIA

Virginia Radiological Society.—*Secretary*, Charles H. Peterson, M.D., 603 Medical Arts Bldg., Roanoke.

WASHINGTON

Washington State Radiological Society.—*Secretary-Treasurer*, Kenneth J. Holtz, M.D., American Bank Bldg., Seattle. Meetings fourth Monday of each month at College Club, Seattle.

WISCONSIN

Milwaukee, Roentgen Ray Society.—*Secretary-Treasurer*, Irving I. Cowan, M.D., Mount Sinai Hospital, Milwaukee. Meets monthly on first Friday at the University Club.

Radiological Section of the Wisconsin State Medical Society.—*Secretary*, Russel F. Wilson, M.D., Beloit Municipal Hospital, Beloit. Two-day annual meeting in May and one day in connection with annual meeting of State Medical Society, in September.

University of Wisconsin Radiological Conference.—*Secretary*, E. A. Pohle, M.D., 1300 University Ave., Madison, Wis. Meets every Thursday from 4 to 5 P.M., Room 301, Service Memorial Institute.

CANADA

Section on Radiology, Canadian Medical Association.—*Secretary*, W. J. Cryderman, M.D., Medical Arts Bldg., Toronto.

Section on Radiology, Ontario Medical Association.—*Secretary*, W. J. Cryderman, M.D., 474 Glenlake Avenue, Toronto.

Canadian Association of Radiologists.—*Honorary Secretary-Treasurer*, A. D. Irvine, M.D., 510 Tegler Bldg., Edmonton, Alberta.

La Société Canadienne-Française d'Eléctrologie et de Radiologie Médicales.—*General Secretary*, Origène Dufresne, M.D., Institut du Radium, Montreal. Meetings are held the third Saturday of each month, generally at the Radium Institute, 4120 East Ontario Street, Montreal; sometimes, at homes of members.

CUBA

Sociedad de Radiología y Fisioterapia de Cuba.—Offices in Hospital Mercedes, Havana. Meetings are held monthly.

ABSTRACTS OF CURRENT LITERATURE

ROENTGEN DIAGNOSIS

THE HEAD AND NECK

Cerebral Arteriography, Its Place in Neurologic Diagnosis. Sidney W. Gross. Arch. Neurol. & Psychiat. **46**: 704–714, October 1941.

The author discusses cerebral arteriography in its various aspects and recommends diodrast in a 50 per cent solution for this procedure. He describes the technic of injection, the preparation of the patient, the surgical instruments necessary to perform the test, and the appearance of a normal arteriogram. He and his associates have performed cerebral arteriography on 21 patients, and 7 cases are presented in detail.

Gross believes that cerebral arteriography is an important adjunct to neurologic diagnosis but that it should be used only when an accurate decision cannot be made by other means. The procedure is particularly recommended for the detection and localization of intracranial aneurysms or angiomas. It is regarded as without danger when 10 to 12 c.c. of a 50 per cent solution of diodrast are injected

[For an outline of the technic see Gross' paper in Radiology **37**: 487, October 1941.—ED.]

CORNELIUS G. DYKE, M.D.

THE CHEST

Special Indication for Apical Thoracoplasty. G. Rossel. Schweiz. med. Wchnschr. **71**: 1158–1160, Oct. 4, 1941.

Pleurisy complicating pneumothorax is serious, and in the type which the author terms "arched pneumothorax" it is practically a constant finding. Although this type of pneumothorax has a certain therapeutic efficacy, it is basically a poor pneumothorax. It consists of an arched apical adhesion of the lung to the parietal wall, preventing apical collapse. Apical lesions, and particularly cavities, are often associated with it. Freeing the adhesion by cautery is prevented by the manner of attachment. A self-sustaining pleurisy seems to result from this lesion.

For this condition an apical thoracoplasty is the ideal treatment; it should be done as soon as possible, before the pleura becomes too greatly thickened. This leads to a collapse of the apex of the lung and clearing of the sputum, but, paradoxically, seems to favor re-expansion of the base, if this was previously collapsed by pneumothorax. Two cases are reported.

LEWIS G. JACOBS, M.D.

Anatomic Changes in the Lungs Following Thoracoplasty. Oscar Auerbach. J. Thoracic Surg. **11**: 21–40, October 1941.

A study was made of 134 autopsies on patients in whom a thoracoplasty of one or more stages had been done. Survival after the procedure was of varying duration, up to five years. In 77 patients pneumothorax was induced prior to thoracoplasty; in 49 of these empyema developed and in 21 of this group bronchopleural fistulas occurred. Marked thickening of the pleura developed after thoracoplasty, particularly just under the scar and in the apical region.

In 17 of the 134 cases the cavities were closed but 11 of these closed before surgery was done. In 9 of the 11 operation was undertaken to obliterate empyema pockets. In all cases in which the cavities were closed the bronchi leading to them were obliterated. In 11 cases the cavities were closed by inspissated caseous material and in 6 cases by scar formation. In the 117 cases in which the cavities were patent the draining bronchi were open.

Bronchiectasis was present in 37 cases, but no evidence was present of secondary infection in the dilated bronchi. In the collapsed lung the arteries showed intimal thickening. The amount of fibrosis developing in the collapsed lung was considered to be directly proportional to the extent of pathology prior to the collapse and had nothing to do with the extent or duration of the collapse. A normal lung, the author believes, would not be altered by a long period of collapse. Emphysema developed, as a rule, in the uncollapsed lung.

The author believes his findings encourage optimism as regards the value of thoracoplasty, since approximately 1,500 thoracoplasties were performed during the period of eight years when the 134 cases came to necropsy. The fact that 17 of this necropsy series—though they must have been among the most unfavorable cases—showed closure of cavities was considered remarkable.

H. O. PETERSON, M.D.

Carcinoma of the Lung: Bronchoscopic Aspects. R. H. Betts. New England J. Med. **225**: 519–525, Oct. 2, 1941.

It is only after a complete history and physical examination have been obtained, with laboratory studies and adequate roentgen studies, that bronchoscopy should be done. A diagnosis of pulmonary carcinoma cannot always be definitely made roentgenologically, but is usually suspected. Bronchoscopy is quite accurate in determining the extent of the lesion and its operability.

From the bronchoscopist's point of view, pulmonary carcinoma may be divided into central and peripheral types. The central tumors, comprising about 75 per cent of the total, present themselves proximal to the bifurcation of bronchi of the third order. Peripheral tumors lie beyond this point and cannot be visualized bronchoscopically, though they may be suspected at times from indirect evidence. The central type is the more favorable because it produces symptoms earlier, it can be visualized, a biopsy specimen can be obtained, and growth is slower and metastasis later. Occasionally a pulmonary growth may be seen bronchoscopically before it produces any roentgen signs. Metastatic lesions in the lung cannot, as a rule, be visualized bronchoscopically.

Inoperability is indicated by evidence of extension to an unresectable area of the tracheobronchial tree and extensive paratracheal lymph node involvement. Since the major lymphatic flow of the pulmonary structures is centripetal, the paratracheal nodes are usually the first to be involved; the trachea may become fixed and the carina widened. There may even be invasion of the adjacent tracheal walls.

In a series of 62 verified pulmonary tumors, the diagnosis was established by bronchoscopic biopsy in 46, or 74 per cent.

J. B. McANENY, M.D.

Roentgenology of Whooping Cough. Joseph H. Lapin. Arch. Pediat. **58**: 617–623, October 1941.

In a report on 10,000 roentgenograms taken in 3,000 cases of whooping cough, Smith, in 1927, was able to show in approximately 80 per cent a demonstrable peribronchial thickening, involving chiefly the lower branches of the bronchial tree, and an enlargement of the tracheobronchial lymph nodes. The peribronchial infiltration was explained histologically by peribronchial lymphoid hyperplasia, and the tracheobronchial enlargement was found also to be attributable to lymphoid hyperplasia. A "basal triangle"—an area of infiltration extending transversely from the hilum to the diaphragm—with a honeycomb structure apparent in the area thus marked off, has been described by Göttche and Erös in 40 per cent of cases of uncomplicated pertussis. Gottlieb and Moller described changes in the position of the diaphragm and emphysema of the

lungs, occurring early in the disease. The diaphragm is low, the domes exhibit a steep, roof-like character, and the lungs frequently show diffuse clouding and comparatively slight lighting-up on deep inspiration, as well as swelling of the bronchial and paratracheal nodes. Pincherle stressed the accentuation of the hilar pattern, the presence of ramified cords, and roundish annular formations, which he considered pathognomonic of the disease.

The author very properly points out that all of the above findings, described by various men and at various times, do not constitute a review of pathognomonic signs; they are secondary to and a part of the process engendered by the presence of viscid sputum in the bronchial tree. Valve actions ensue, as in pneumonia, and obstructive emphysema and atelectasis may follow. *There are, therefore, no pathognomonic roentgen signs in whooping cough.*

On theoretical bases it seems reasonable to assume that in the notoriously irregular course of whooping cough pneumonia, with its frequent afebrile spells and exacerbations, every time there is a sharp rise of fever there has been a fresh obstruction of the bronchial tree, followed by atelectasis, emphysema, and then a pneumonia distal to the obstruction.

The author concludes that any drug which diminishes the strength of the cough reflex should be interdicted; also that expectorants may be of value. He has used sodium iodide in doses of 5 to 10 grains every three hours for a one-year-old infant, with good results. Strychnine has been advocated as sharpening the cough reflex, and oxygen may be life-saving when anoxemia becomes apparent.   PERCY J. DELANO, M.D.

THE DIGESTIVE TRACT

Incidence of Hypertrophic Pyloric Stenosis. Arvid Wallgren. Am. J. Dis. Child. **62:** 751–756, October 1941.

The opinion is prevalent among students of hypertrophic pyloric stenosis that the incidence differs widely in different countries, but the number of reports on the disease does not furnish an adequate index of its occurrence in any particular area. The milder forms are apt to be overlooked by the general practitioner where they would be detected by an experienced pediatrician.

At Göteborg, Sweden, the clinic and private practice arrangements are such that nearly all of the healthy and probably all of the sick infants are examined by an able specialist in children's diseases and the risk of the symptoms of hypertrophic pyloric stenosis being overlooked or misinterpreted is reduced to a minimum. In case of doubt patients are given roentgen examination and their disorder is thereby correctly diagnosed. After the ingestion of a contrast meal, hypertrophic pyloric stenosis is seen roentgenographically as a narrow streak, 1 to 2 cm. in length, corresponding to the lumen of the canalis egestorius. While the gastric peristalsis is otherwise normal, the hypertrophied muscle of the canalis is rigid and immobile. The peristaltic waves are, therefore, stopped at the oral end of the stenosed area. As the child grows older the lumen of the canalis widens, more and more food is allowed to pass through, and finally the functional motility of the stomach becomes normal. The muscular hypertrophy, however, persists in a more or less marked degree, and the pathognomonic signs are demonstrable roentgenographically in a less pronounced form for many years after the disappearance of the clinical symptoms.

A survey of the 25,500 children born in Göteborg from 1934 to 1940, inclusive, revealed 102 cases of hypertrophic pyloric stenosis, which amounts to an incidence of 0.4 per cent. The incidence among boys was found to be five times that among girls.

GEORGE M. WYATT, M.D.

Surgical Management of Gastric and Duodenal Ulcers. P. H. T. Thorlakson and A. W. S. Hay. Canad. M. A. J. **45:** 298–307, October 1941.

The authors studied the records of 730 cases of gastric and duodenal ulcer treated over a ten-year period. They believe the patient should be informed that the ulcer diathesis may remain for a lifetime.

It is generally conceded at the present time that peptic ulceration is the result of a combination of central (or nervous) and local factors acting in susceptible individuals. Diagnosis of duodenal ulcer may be based on the clinical history and the finding of an ulcer crater on the roentgen examination. In the diagnosis of gastric lesions gastroscopy is an additional aid.

The ulcer without complications is primarily a medical problem. When medical treatment fails or complications arise, the problem is surgical.

Posterior gastro-enterostomy is advised for gastric ulcer high on the lesser curvature with adhesions to the pancreas, liver, or posterior abdominal wall. Resection is advised for ulcers lower on the lesser curvature, on the anterior or posterior wall.

In the presence of duodenal ulcer posterior gastro-enterostomy is a useful procedure when pyloric obstruction due to cicatricial stenosis is present and when ulcer symptoms, present for many years, are incompletely relieved by medical treatment. Subtotal gastrectomy is indicated in duodenal ulcer under certain definitely established circumstances: (1) for relief of posterior gastro-enterostomy ulcer; (2) for ulcer complicated by severe hemorrhage; (3) for ulcer associated with marked gastritis or gastric ulcer; (4) for chronic ulcer with intractable pain, especially in a nervous person with high acidity. The authors emphasize the fact that subtotal gastrectomy is not advocated as a routine procedure. Local pyloroplastic procedures are as a rule of little value in the surgical management of duodenal ulcer.

When it is indicated, treatment should include psychotherapy.   M. L. CONNELLY, M.D.

Rôle of the Roentgenologic Examination in the Diagnosis of Intestinal Obstruction. E. P. Pendergrass. New England J. Med. **225:** 637–641, Oct. 23, 1941.

Along with the question of the possible presence of intestinal obstruction there are the problems of its location, whether it is single or multiple, its completeness, its cause, and whether it is of acute development or the final stage in a slowly developing lesion. Fluoroscopy is of advantage to determine mobility of the diaphragm and the best position for obtaining films. Films taken with the patient upright, horizontal, or on his side may be required to show fluid. The collection of gas in the bowel or peritoneal cavity, the presence of the pre-peritoneal fat line, presence of muscle shadows, thick shadows of the intestinal walls, and soft tissue masses, are important points to be observed.

Intestinal gas shadows are due to gas produced by digestive processes, that diffused from the blood, and swallowed air, the last accounting for about 68 per cent of the gas shadows in intestinal obstruction. Abnormal gas shadows may be produced also by morphine and other sedative drugs, peritoneal irritation, dysentery, bacterial infections, nutritional deficiencies, rupture of a graafian follicle, and debilitating conditions such as diabetes and sickle-cell anemia.

The location of the obstruction is important to determine. Frequently reconstructive operations on the stomach are followed by delay in emptying, which may suggest mechanical obstruction. This is actually due, however, to the operative trauma, hypoproteinemia, or vitamin deficiency and clears up after a few weeks. If the gas shadows are limited to the colon and symptoms are acute, the obstruction is probably colonic and probably mechanical. A barium enema is of advantage here. Usually, paralytic ileus causes distention of the

large and small intestine and offers no difficulty in the differential diagnosis.

Small bowel obstruction gives a characteristic pattern and, with the aid of intubation, the position and at times the nature of the obstruction can be determined.

Incomplete intestinal obstruction is usually studied by means of the barium meal or enema. Intubation is a help at times.

Among the causes of obstruction are intussusception, volvulus, new growth, adhesions, and inflammation. Multiple obstructions may be due to many causes, but especially adhesions, metastatic cancer, the effects of irradiation, and inflammatory lesions.

J. B. McANENY, M.D.

THE SKELETAL SYSTEM

Aseptic Necrosis of the Femoral Head Following Traumatic Dislocation of the Hip. S. W. Banks. J. Bone & Joint Surg. 23: 753–781, October 1941.

Complete recovery is usually assumed in traumatic dislocations of the hip when, after immobilization, pain disappears and normal motion returns. This, however, is not always the case. It is now known that in spite of apparent recovery, pain and disability in the previously dislocated hip may recur after months or, exceptionally, years, due to aseptic necrosis of the femoral head. This condition has been observed in children and in adults. It is caused by disruption of a major portion of the blood supply to the femoral head at the time of dislocation.

The blood supply to the head of the femur is through the round ligament and from the anterior and posterior circumflex femoral arteries that pass through the capsule of the joint and enter the femoral neck. In a dislocation, the round ligament is always torn, but all dislocations are not followed by necrosis. The vessels of the neck may also be torn in a dislocation and the fact that the aseptic necrosis often involves the head and part of the neck suggests that injury to these vessels plays a part in its production. Further study is necessary to clarify this point.

Pathologically, the entire head, including the cortex, trabeculae, and marrow, becomes necrotic. The articular cartilage may survive. With the re-establishment of circulation, highly vascular connective tissue invades the neck and head, and absorption of the dead bone and marrow and replacement by living bone and marrow follow. In the new-formed bone, the trabeculation is irregular and less dense than in the dead bone, making it possible to distinguish it in the roentgenogram. An osteo-arthritis frequently is seen, characterized by villous synovitis, acetabular sclerosis, marginal osteophytes, and occasionally loose bodies in the joint.

Atrophy of disuse in the adjacent living bone of the shaft and pelvis following dislocation is a prerequisite to roentgen diagnosis. Ordinarily three or four months must elapse before this is of sufficient degree to permit contrast with the dense dead osseous structures of the aseptic necrosis.

When the patient begins to use the hip, pain and restriction of movement occur, due to collapse of the head or degenerative arthritis. This is the first sign of aseptic necrosis. Roentgenograms at this time will show late evidence of necrosis: dense dead bone, irregular new bone, fragmentation, alterations in the shape of the head, and arthritic changes.

Since femoral head necrosis cannot be detected for several months after injury, two courses of treatment are possible for traumatic hip dislocation. Either the patient is prohibited to use the extremity for weight-bearing for six or eight months, when the atrophy will define the necrotic region, or if the extremity is used after the post-reduction period, it should be examined at frequent intervals for at least two years.

Forty-two cases of aseptic necrosis of the femoral head appear in the literature. The 35 occurring in adults are tabulated here and 9 additional cases are presented and discussed.   J. B. McANENY, M.D.

Milkmann's Disease. Max Lüdin. Schweiz. med. Wchnschr. 71: 1297–1298, Oct. 25, 1941.

Milkmann's disease, a band-like decalcification of bone usually found in the upper femur, which may progress to fracture, is quite rare. Hopf is cited as reporting 12 cases from the literature and 3 of his own; the author has seen 4 cases, one of which he reports here. The condition often appears in women near the climacteric, although one of the patients seen by the author was a man of 63. Therapy with arsenic, roentgen rays, and hormones has been a failure, but good results have been obtained by treatment with calcium, vitamin D, and ultraviolet (or solar) irradiation.

LEWIS G. JACOBS, M.D.

Perandren in Poor Callus Formation. E. Hagenbach. Schweiz. med. Wchnschr. 71: 1212–1215, Oct. 18, 1941.

The author, a 66-year-old surgeon, reports his own case. A fracture of the right ulna in the lower third was produced by a direct blow. After six weeks callus was poor and a pseudarthrosis seemed to be forming. Further immobilization for an additional eight weeks accompanied by the administration of 420 mg. of perandren Ciba in divided doses was followed by solid bony union. The author discusses whether this may be accepted as a proof that the good result was due to the perandren, and feels that it may. As a complication he suffered a median nerve neuralgia of considerable severity.   LEWIS G. JACOBS, M.D.

Hemangioma of Vertebrae. R. K. Ghormley and A. W. Adson. J. Bone & Joint Surg. 23: 887–895, October 1941.

In a good review of the literature the authors pay particular attention to the autopsy findings of Schmorl on hemangioma of the spine. They then classify and discuss their own clinical series of 39 patients.

Group 1. These five patients had hemangioma with paraplegia and were operated upon, with or without subsequent irradiation. One died in six weeks without improvement; one died six years later of a cerebral accident. The remaining 3 improved or recovered.

Group 2. These 5 patients had symptoms of compression of the spinal cord but no paraplegia. All received roentgen therapy, which would appear to be definitely beneficial. One patient did not improve; 2 improved, and 2 were well four and six years after diagnosis.

Group 3. Nine patients with hemangioma complained of local pain but showed no cord compression. Two were treated with a brace without improvement. Seven were irradiated, and of these, 3 improved; 1 had not been followed sufficiently long for conclusions, and the result in 1 was unknown. Two did not follow the treatment prescribed.

Group 4. These 20 patients had hemangiomata without symptoms referable to the vertebrae and were not followed; the possibility of future complaints in this group must be kept in mind.

The symptoms of vertebral hemangioma are localized pain, muscle spasm, and rigidity of the spine. Later hyperesthesia, hypesthesia, radiculitis, and complete transverse myelitis may develop. No symptoms may be present. Crushing or ballooning of the vertebrae may occur and may result in paralysis.

Hemangioma may simulate a benign neoplasm of the cord in its symptoms, but these develop more rapidly. Metastatic lesions to the spine must also be considered but these show even more rapid progress. Roentgeno-

graphic studies reveal enlargement of the intertrabecular spaces and absorption of some trabeculae and thickening of others, which is quite characteristic. Some workers have described ballooning of the walls of the vertebrae and pathological fracture.

Roentgen therapy is given as follows: 500 r to each of four fields over the involved area, with 135 kv., 16 inches distance, 5 ma., and 6 mm. aluminum filtration. Three or four treatments with intervals of four to six weeks are given and then one or two treatments each year for four years.   J. B. McANENY, M.D.

Osteochondritis Dissecans of Ankle Joint. Use of Tomography as a Diagnostic Aid. M. D. Mensor and G. F. Melody. J. Bone & Joint Surg. **23**: 903–909, October 1941.

A 34-year-old male fractured his right ankle. Roentgen examination, in March 1940, showed a compression fracture at the distal end of the tibia and a comminuted fracture of the internal malleolus. Another roentgenogram, November 1940, showed good healing but no other injury. In December 1940, tomograms showed a loose fragment of bone in the posterior portion of the joint space, measuring 2.0×0.5 cm. The joint was opened, the loose fragments were removed, and the patient regained good function of the joint, without restriction or instability.

This would seem to be the twentieth case of osteochondritis dissecans of the ankle joint reported in the literature, and the first reported in which diagnosis was made only as a result of tomographic investigation.

J. B. McANENY, M.D.

THE GENITO-URINARY TRACT

Simple Cysts of the Kidney. Edward L. Peirson and Grant M. Dixey. Urol. & Cutan. Rev. **45**: 309–314, May 1941.

Eleven cases of renal cysts are here recorded. Seven patients had solitary or simple cysts and 4 multiple cysts. In these cases the multiple cysts are unilateral in contradistinction to bilateral involvement in polycystic kidneys. Cysts may cause mechanical interference with normal renal function.

The authors mention the diversity of opinion as to the etiology of simple renal cysts. In their series the average age at diagnosis was fifty-three years and the youngest patient was thirty. This corresponds closely to other reported series and suggests that the condition is acquired rather than congenital.

The symptoms are variable and diagnosis is wholly dependent upon the pyelogram. Even the pyelographic findings show wide variation, however, and are not regarded as sufficiently characteristic for absolute differentiation from malignant tumors. Visualization of the cyst outline is helpful in distinguishing a cyst from a solid tumor, as the latter tends to grow into rather than away from the kidney. This finding is of particular value if the psoas muscle or kidney outline can be seen through the cyst shadow, as they are likely to be obscured by the more solid neoplasm. Obliteration of a calyx is more likely to occur in cases of malignant tumors because of their invasive character. In cases of cystic disease the defect is due solely to pressure and tends to be smooth and round without evidence of irregularity in the filling of the pelvis or calyces. Whereas a malignant tumor may markedly destroy functioning kidney tissue, there is seldom extensive destruction of tissue due to the growth of a cyst. Thus, in the latter condition a good shadow is usually obtained by intravenous pyelograms unless the cyst has produced secondary destruction of kidney tissue by causing obstruction to the urinary outflow and resulting hydronephrosis.

While in most of the authors' cases a preoperative diagnosis was made, the error was of sufficient proportions to convince them that surgical exploration should be done in all cases of kidney tumor. In 7 of the reported cases partial excision of the cyst and cauterization of the remaining cyst wall gave a satisfactory result.   MAURICE D. SACHS, M.D.

Perinephric Abscess in Children. Harry M. Greenwald and Philip J. Kresky. Urol. & Cutan. Rev. **45**: 289–295, May 1941.

Thirty-three cases of perinephric abscess in children under 15 years of age are reported; 29 (87.9 per cent) of these cases were extrarenal in origin. The majority of the patients (68.4 per cent) gave a history of pyogenic skin or upper respiratory infection as the primary source, with a resultant hematogenous spread. *Staphylococcus aureus* was recovered in 65.5 per cent of the cases. The time interval between the onset of symptoms and the localization of the infection was one to five weeks. Mortality was high (21.2 per cent), especially in children under three years of age. There were no deaths in children over seven years of age. The importance of x-ray in early diagnosis of perinephric abscess is discussed. Lateral pyelographic studies were of definite diagnostic value in showing anterior displacement of the colon.

MAURICE D. SACHS, M.D.

RADIOTHERAPY

MALIGNANT NEOPLASMS

Radiotherapy of Cancer of the Cervix. Maurice Brouha. Schweiz. med. Wchnschr. **71**: 1240–1242, Oct. 25, 1941.

This is a report of the results of radiotherapy in cervical cancer at the Anti-Cancer Institute of the Faculty of Medicine of the University of Liège. In general, the plan of treatment calls for radium followed by x-rays: 26.5 mg. of radium element are inserted into the cervical canal and 6.66 mg. into each lateral fornix. This is left about seven days for a total dose of 50 mcd. (or 6,650 mg.-hr.). Filters are 1 mm. platinum, 1.25 mm. gold, and the thickness of the rubber catheter applicator. Heavier doses lead to irritation of the bladder and rectum with subsequent necrosis. Four to six weeks after the application of radium, x-ray is given; up to July 1930, 16,000 r were given over four skin portals in sixteen treatments; subsequent to July 1930, 10,800 r were divided among

six skin portals in 36 treatments over a period of about six weeks. This radiation is generated at 200 kv. and filtered through 1 mm. of copper and 0.2 mm. of aluminum.

In 602 cases treated in 1925–1936 there were 171 five-year survivals (28.25 per cent). When the cases are broken down into stages one to four (presumably Heyman's League of Nations classification, though this is not specifically stated) the five-year survivals were 51.3 per cent, 34.7 per cent, 14.1 per cent, and 4.4 per cent, respectively. Tables giving a somewhat more complete breakdown by years according to the plan in the League bulletins are included.

LEWIS G. JACOBS, M.D.

Osteogenic Sarcoma. Carl E. Badgley and Martin Batts, Jr. Arch. Surg. **43**: 541–550, October 1941.

Eighty cases of osteogenic sarcoma were analyzed. Forty per cent of the patients were in the second decade, with a range of from eight to seventy-two years;

64 per cent were males. Preceding trauma was noted in about a third of the cases. The average duration of symptoms was thirteen months, with a spread of from two weeks to ten years. Pain and swelling were the most prominent symptoms. General health was good. A palpable tumor was noted in 91 per cent, and increased heat was frequent. In lesions near a joint limitation of motion was present. Ulceration of the skin had occurred in 5 patients. The most common site was the ends of the long bones. Histologic proof of the diagnosis had been obtained in 62 cases; in 18 a clinical diagnosis only was made. The tumors were classified according to Geschickter and Copeland's scheme, and most of the patients were found to have primary myxochondrosarcoma, secondary chondrosarcoma, or sclerosing osteogenic sarcoma.

Of the 80 patients, 19 per cent survived five years or over; 4 patients have been well over ten years, but not all the group has been followed so long. One died of pulmonary metastases after thirteen years.

The treatment advocated is amputation. The necessity of amputation above the next joint is not borne out by this study. Local excision plus roentgen therapy may be used in lesions not suitable for amputation. The longer the patient survives after treatment the better the chance of cure.   LEWIS G. JACOBS, M.D.

Gradation of Ewing's Tumor (Endothelial Myeloma).
W. C. Campbell and J. F. Hamilton. J. Bone & Joint Surg. 23: 869–876, October 1941.

This is an attempt to grade endothelial myeloma much as carcinoma has been graded by Broders, The clinical findings, roentgenographic evidence, and therapeutic results are correlated with the microscopic data. Thirty cases are examined.

Clinically, pain, worse at night and with intervals of freedom, is the most constant finding. The condition of the skin, circulation, and temperature are of little diagnostic value.

The average "tumor life" of 17 patients with symptoms up to a year was one year and five months, but 8 patients with symptoms over a year in duration had an average tumor life of five years and seven months. This difference, it is believed, may be explained by the difference in mitotic count in the two groups: 7.2 in the first and 6.3 in the second. A long tumor history may be associated with diminished cellular activity.

The average tumor life of 9 patients with primary tumor of the pelvis, ribs, and spine was two years and one month with an average mitotic figure count of 7.4, while the average tumor life of 15 patients with tumor of the extremities was three years and four months, with an average mitotic figure count of 6.4.

The roentgenographic findings in Ewing's tumor are divided into three stages: (1) condensation of the shaft of the bone without reaction of the periosteum; (2) typical invasion with expansion, striation and destruction of the cortex, and reactive bone production of the periosteum in layers; (3) disintegration of the periosteal layers and shaft with extension to surrounding parts. Six patients seen in the first stage had an average tumor life of one year and nine months, and an average mitotic-figure count of 8.2. Twenty-three patients were seen after destruction of bone had occurred, with an average tumor life of two years and eleven months, and an average mitotic-figure count of 7. It is possible that the real factor in prognosis is the cellular activity as measured by the mitotic-figure count.

Treatment consisted of amputation, resection, roentgen therapy, and Coley's toxins. Of the 4 living patients (13.3 per cent), one was treated by amputation, living fourteen years; the second received roentgen therapy and Coley's toxins, living ten years and nine months; the third had radium, roentgen therapy, and amputation and lived five years and six months; the fourth received roentgen therapy and Coley's toxins,

living three years and six months. In 3 of these patients the mitotic-figure count was 1 to 5 per high-power field and the other had a count of 6.

Microscopically the tumor grows in solid sheets of polyhedral cells with fairly uniform nuclei and no intracellular stroma, either completely differentiated or totally undifferentiated. Of the two patients who lived the longest, one had no spindle-shaped nuclei while the other had many.

The group of tumors were graded 1 to 4 according to the number of chromatin knots. Three tumors were classified as Group 1, with 1 patient still living, the average tumor life of the others being two years and four months. Ten were in Group 4, and all are dead, after an average tumor life of three years and four months. None of Groups 3 and 4 is living. One patient of Group 1 is living fourteen years, and 3 patients of Group 2 lived ten years and nine months, five years and six months, and three years and six months. The value of this criterion is doubtful, but suggests greater malignancy in tumors of numerous chromatin knots.

On the basis of mitotic figures per high-power field the grading used is: Grade 1, 1 to 5 figures; Grade 2, 6 to 10 figures; and Grade 3, 11 to 15 figures. Of the 4 living patients three had Grade 1 and one Grade 2 tumor (6 figures or just within Grade 2). In Grade 1 tumors the average tumor life is three years and nine months, the longest eleven years and the shortest eleven months. In Grade 2 patients the average tumor life is three years and nine months, the longest nine years and six months and the shortest one year and five months. In Grade 3, the average tumor life is one year and 6 months, the longest two years and ten months, and the shortest eight months. Although a definite prognosis of years of expectancy cannot be made, one can say that a patient with a mitotic-figure count of 5 or less has a 2 to 1 better expectancy than one with a count of over 10.   J. B. MCANENY, M.D.

Postirradiation Changes in the Levels of Organic Phosphorus in the Blood of Patients with Leukemia.
J. C. Abels, J. M. Kenney, L. Craver, L. D. Marinelli, and C. P. Rhoads. Cancer Research 1: 771–775, October 1941.

The effects on blood phosphorus of subtherapeutic doses of radioactive phosphorus (approximately 1.5 mc. P^{32}), total exposure of the body to roentgen rays, and irradiation of the cardiac area were investigated in 6 patients with chronic myeloid or lymphatic leukemia. Ingestion of the radioactive substance was followed by a rise in the organic acid-soluble phosphate levels of the leukocytes and red cells. Comparable changes, however, occurred after the administration of a dose of 3–15 r to the total body surface, or 20 r to the precordial zone. The latter exposure was assumed to deliver 2 r to the entire volume of blood circulating through the heart during the period of irradiation. Treatment with non-radioactive phosphorus (Na_2HPO_4) exerted no effect on the phosphorus content of the blood cells. Since the radioactive isotopes are being employed in studies on metabolism, the authors suggest that such investigations may not interpret strictly physiologic levels. It is important to realize that the results have been affected by the biochemical influences of small doses of radiation. As the present studies have not been carried out in normal subjects, it is possible that the observed effects may occur only in leukemic patients.   MILTON J. EISEN, M.D.

NON-MALIGNANT CONDITIONS

Sarcoidosis, or Besnier-Boeck-Schaumann Disease.
Warfield T. Longcope. J. A. M. A. 117: 1321–1327, Oct. 18, 1941.

Sarcoidosis appears in a great variety of clinical forms. The cause, the relationship to tuberculosis, the

pathogenesis, the treatment, and the manner by which recovery ensues remain matters of controversy and dispute. The disease can no longer be considered a rarity. The author reviews the observations made on 31 patients, 5 of whom have died. The clinical diagnosis was made or confirmed in every instance by histologic examination of a lymph node, a nodule in the skin, or the organs at autopsy. The disease was seen much more commonly among negroes than among white persons.

Since there is frequently involvement of either the superficial lymph nodes or the skin, material can usually be obtained for histologic examination and accurate diagnosis.

The characteristic pathologic lesion is the so-called hard tubercle. This consists of a microscopic collection of large pale-staining polygonal epithelioid cells forming a mass about the size of a miliary tubercle. The clusters of cells are almost always devoid of a peripheral inflammatory zone and without central necrosis. Giant cells are not regularly present but are common. These contain peculiar inclusions of various sizes and shapes, staining deeply in hematoxylin. They were first described by Schaumann and have been repeatedly observed since his report as characteristic of the disease. They sometimes give the appearance of calcified material. The tubercles appear to remain unchanged for long periods. They do not grow larger but they increase in number. The histologic picture on the whole is one of a proliferative rather than of an inflammatory process.

The disease may affect any organ in the body and is prone to appear in lymphoid tissue. Though sarcoidosis at times presents more or less acute phases, the usual lack of constitutional reactions in the presence of extensive disease of many organs is one of its most surprising features. Fever is not common. The occurrence of eosinophilia has occasioned some comment.

Symptoms, when they exist, are caused by the mechanical interference with the function of organs rather than by any form of intoxication. Involvement of any or all of the structures of the eye is comparatively common during some stage of the disease. This occurred in 16 of the author's 31 cases. In many it was mistaken for tuberculosis or syphilis. Too often the sight is destroyed or enucleation is required. In 7 of the 16 patients disease of the eye formed a part of the syndrome known as uveoparotid fever.

A remarkable type of involvement of the mediastinal and bronchial lymph nodes and of the lungs produces a second rather distinctive clinical form of the disease. This is common and occurred to a greater or less extent in at least 28 of the patients. One of the most astonishing features is that in some of these the roentgenogram showed an extensive infiltration of both lungs when there were absolutely no symptoms or physical signs that would suggest pulmonary disease. Dyspnea is, however, one symptom of this form of the disease, though it occurred in noticeable form in only 7 out of 31 patients.

With spreading involvement of the lung, secondary pulmonary infections may sometimes arise, causing attacks of bronchopneumonia. Patients with such involvement also seem to be susceptible to tuberculosis.

The function of the heart may be deranged, either secondarily as a result of extensive infiltration of pulmonary tissue or by direct invasion of the pericardium or the myocardium by sarcoid. In 5 of the author's 31 patients some evidence of myocardial damage was obvious during life. All had enlargement of the heart; 2 who came to autopsy showed more or less extensive invasion of the myocardium by sarcoid.

There are many interesting clinical syndromes growing out of the involvement of other organs or groups of organs. Reference is made to the patients reproducing more or less the lupus pernio of Besnier, in which the striking enlargement of the nose, the lesions on the ears, and the knotty swellings about the joints of the fingers and toes, with deposits in the phalangeal joints, produce an appearance somewhat suggestive of leprosy. In other instances the excessive enlargement of the spleen and the liver has led to the diagnosis of Banti's disease. The abdominal lymph nodes may become greatly enlarged. Diabetes insipidus may occur. Autopsy in these cases has showed infiltration of the pituitary gland with sarcoid tissue.

Benign lymphogranulomatosis is likely to run a long course, during which relapses, with involvement of different organs and tissues, alternate with quiescent or latent periods. Though spontaneous recovery eventually takes place in most instances, the relapses may continue for years. The appearance of eosinophilia has already been mentioned. The sedimentation rate is sometimes elevated during the active phase of the disease. The cholesterol content was below 200 mg. per 100 c.c. in 4 cases and above 200 in 1. The level of calcium in the blood must be considered as a high normal or above.

A most remarkable alteration is observed in the plasma proteins. This consists in an unusual increase in the globulin fraction, resulting sometimes in pronounced elevation of the total plasma protein. In this respect sarcoidosis may be classed with such diseases as multiple myeloma, kala-azar and lymphogranuloma venereum. Bing concluded that an excessive production of plasma globulin is frequently associated with widespread proliferation of the reticulo-endothelium.

Attention is called to the rarity with which patients with sarcoid show reactions to tuberculin. The author has not obtained any evidence to support the view that the disease is caused by human, bovine, or avian tubercle bacilli. We are left in ignorance of the cause of this disease.

All methods of treatment are empiric. Ultraviolet rays are used routinely and the author believes they influence the enlargement of the superficial lymph nodes and lesions of the skin.

CLARENCE E. WEAVER, M.D.

Naevus Unius Lateris. George T. Pack and Douglas A. Sunderland. Arch. Surg. **43**: 341–375, September 1941.

Four cases of nevus of unilateral distribution are presented with an analysis of 156 cases found in the literature. This is a rare form of congenital tumor, constituting 0.01 per cent of the tumors seen at Memorial Hospital (New York). Its more typical characteristics are (1) linear distribution following the long axis of a limb or directed transversely around the trunk; (2) unilateral distribution; (3) papillary or verrucous character; (4) congenital origin, although lesions may appear later in life; (5) sensory disturbances (though these may be absent); (6) variable progress.

Theories of etiology are rather varied. None is well substantiated. Of the 4 patients described, 3 died of cancer, which in 2 cases was associated with the nevus. In the 156 cases found in the literature the white race was most often involved and the sex distribution was about equal. The extent of involvement varied from a comparatively small patch to almost the entire half of the body, and the two sides were involved with about equal frequency. In half the cases the nevus appeared at or soon after birth, but in some cases it was first seen well on in middle life. In most cases heredity did not appear to be a factor. Most of the nevi are pigmented, but the pigment appears to be dirt in the papillary folds rather than melanotic pigment. In about a third of the cases the tumors were believed to follow a nerve distribution.

The microscopic picture shows a hyperkeratosis, parakeratosis, and slight acanthosis of the epidermis, with or without edema; increased thickness of the stratum granulosum and stratum spinosum; irregular

elongation of the papillae; and round-cell infiltration of the papillary layer and corium.

In less than 10 per cent of the cases were symptoms observed; these usually consisted of itching. Symptoms, when present, were generally due to complications.

Treatment has not been standardized, as so few cases are seen by any one physician. While irradiation commonly causes some improvement, it is not curative unless carried to the point of cauterization. Sharp excision with plastic repair is the treatment of choice. The course of the disease is variable; it may remain stationary, progress, or regress spontaneously. Other abnormalities, congenital or otherwise, sometimes accompany the condition. The relationship of this tumor to carcinoma should be more completely investigated.

This excellent review is well illustrated and contains a rather full bibliography, said to be more complete in the reprints.   LEWIS G. JACOBS, M.D.

EXPERIMENTAL STUDIES

Roentgen Radiation of Papilloma Virus (Shope): II. Effect of X-Rays upon Papilloma Virus in vitro. J. T. Syverton, G. P. Berry, and S. L. Warren. J. Exper. Med. **74:** 223–234, September 1941.

The Shope papilloma is a benign, infectious, cutaneous tumor of rabbits. It occurs in nature in the cottontail rabbit, and virus extracted from such spontaneously occurring lesions will induce papillomas in other cottontails or in domestic rabbits. These tumors are not infrequently followed by cancers.

Having previously studied the effect of radiation on the Shope papilloma in vivo (J. Exper. Med. **73:** 243, 1941. Abst. in Radiology **37:** 390, 1941), the authors now turn to the effect of the roentgen ray upon a cell-free suspension of the virus in vitro. The irradiation was given at 90 kv., 40 ma., with no filter other than the inherent filtration of the tube, at a distance of 6 cm. The cell-free virus was put in a small Petri dish and this was set on top of a rotating stand so that the dish rotated throughout the period of irradiation, thus enabling a more uniform distribution to the entire contents. In each experiment the irradiation was continuous and was done with the same tube. It is estimated that the dosage delivered was correct to within ±5 per cent.

The first experiment consisted of irradiation with doses of 10,000 to 200,000 r. These amounts had no effect upon the interval of time between inoculation and the appearance of the papilloma and the titer of the virus. Virus was readily recovered from the papillomas induced in the cottontail rabbits. This amount of irradiation also had no effect upon the size of the tumors obtained.

In the second experiment the dose was carried to 3,000,000 r. At 3,000,000 r the titer of the virus was reduced from 10 to 1,000-fold. This amount of irradiation did not have much effect, if any, on the incubation period. It was observed, however, that the resulting tumors were much reduced in size. The virus was regularly recovered from the cottontail rabbits.

A third experiment consisted in dosages carried to 7,302,000 r. Here it was noted that amounts of 2,000,-000 r probably had elicited some effects as shown by some prolongation of incubation period and possibly by 100-fold loss in titer. Dosages of 3,000,000 r or more resulted in from 10 to 100,000-fold loss in titer and in a change from an incubation period of twelve to thirty-two days to one of fifteen to thirty-four days. The effect of 4,000,000 r was more pronounced. Dosages of approximately 6,000,000 to 7,000,000 r were uniformly effective in inactivating the virus.

In the fourth experiment the dose was carried to 14,325,000 r, and the results in the preceding experiment were confirmed and extended.

The authors conclude that cell-free suspensions of papilloma virus (Shope) require for their inactivation in vitro amounts of roentgen irradiation that are much greater than those needed to inactivate other infectious agents previously described. These amounts are several thousand times greater than those required to eradicate permanently papillomas induced by the virus in domestic rabbits. Roentgen irradiation of materials containing papilloma virus provides a method whereby bacterial invaders may be eliminated from papillomatous material. The bacteria will be destroyed by 2,000,000 r without obviously injuring the papilloma virus.   ANDREW H. DOWDY, M.D.

Effects of Ultraviolet Radiation on Sodium Thymonucleate. Alexander Hollaender, Jesse P. Greenstein, and Wendell V. Jenrette. J. Nat. Cancer Inst. **2:** 23–28, August 1941.

The authors investigated the action of ultraviolet rays (non-monochromatic, mostly 2537 Å.) on sodium thymonucleate, with the purpose of interpreting the rôle of nucleic acid in determining the sensitivity of cells to ultraviolet radiation.

The irradiation of solutions of sodium thymonucleate produced a diminution of viscosity and of the birefringence of flow. By means of an ingenious experiment (irradiation of Bacilli coli suspended in solutions of sodium thymonucleate and count of the surviving bacteria), the authors tried to estimate the dose of radiation (quanta per molecule) which produces a definite amount of change in the properties of the solutions. The results are interpreted as indicating that ultraviolet rays depolymerize the highly asymmetric molecules of sodium thymonucleate into smaller, less asymmetric molecules. A dose of the order of 10^4 ultra-violet quanta absorbed per molecule is required for such splitting. The absorption spectrum of the solution remains the same after irradiation.

The relationship of these results to radiobiology is discussed.   S. E. LURIA, M.D.

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